As Vice President and General Manager of MARCO Pollution Control, Paul sold and oversaw the construction and delivery of new capital equipment in 10 countries on 6 continents, in addition to capturing US Navy business domestically. To overcome import restrictions overseas, he set up local manufacturing operations through direct licensing or the formation of strategic alliances with local suppliers.

While with the Hudson Companies, Paul served as an engineering and management consultant to marine facility owners, vessel owners and their underwriters. Responding to more than two dozen marine casualties, he assessed damage and designed temporary or permanent repairs. He served as salvage engineer or salvage master, and assembled project teams to carry out restorations on behalf of owners. He also facilitated dispute resolution for underwriters.

As manager of marine services for Tracor Marine, Paul managed the Emergency Ship Salvage Materials (ESSM) response program and the Gulf Zone Salvage Contract for the US Navy Supervisor of Salvage. The ESSM program holds a billion-dollar inventory of emergency equipment for rapid deployment from warehouses positioned around the world. As a Navy Salvor, he served as salvage engineer and project manager on numerous SUPSALV task assignments, including the Space Shuttle *Challenger* recovery.

Contributing author and editor to the following:

Marine Casualty Response: Salvage Engineering, American Society of Naval Engineers
Ship Design and Construction, 3rd Edition, Society of Naval Architects and Marine Engineers

BENJAMIN B. ACKERS, P.E.

Occupation	**Senior Associate, Naval Architect**
Experience	1994 - 1997 Webb Institute Intern Programs • Winter 1994: Marine Industries Northwest Inc. • Winter 1995: Keystone Shipping Co. • Summer 1995: Designers and Planners • Winter 1996 : National Steel & Shipbuilding • Summer 1996: Designers and Planners • Winter 1997 : The Glosten Associates, Inc. 1997 - present The Glosten Associates, Inc.
Education	Webb Institute of Naval Architecture, B.S., Naval Architecture and Marine Engineering, 1997 University of Washington, Masters of Business and Administration, 2004
Licensing / Certifications	Washington, 2002, Naval Architecture/Marine Engineering
Memberships	Society of Naval Architects and Marine Engineers

RELEVANT WORK EXPERIENCE

Ben came to The Glosten Associates after his graduation from Webb Institute of Naval Architecture in 1997. In his time at Glosten, Ben has contributed to projects involving maneuvering, seakeeping, resistance and propulsion, finite element analysis, dynamic loads analysis, structural fatigue, wake wash, transportation system modeling and analysis, and stability for vessels including oil tankers, barges, ferries, research vessels and supply vessels. While continuing to work full time, Ben earned his MBA at the University of Washington in 2004.

During his senior year at Webb, Ben co-authored a paper for presentation at the 1997 SNAME Annual Meeting. The paper required Ben to participate in an extensive model test program and perform a comprehensive resistance analysis. Researching the high-speed trimaran hullform concept, required developing new methods of analysis and applying them to a large amount of experimental data.

Ben was extensively involved in the design of a SWATH Coastal Research Vessel for Woods Hole Oceanographic Institute. In support of the design, his responsibilities included subdivision, stability, seakeeping performance, dynamic loads analysis, weight estimating, structural design and finite element analysis.

Ben has participated in two major transportation studies for the State of Alaska. In the first, a study of marine alternatives for improved access to Juneau, Alaska, he assisted in the modeling of vessel performance. In the second, a vessel suitability study for the Southeast Alaska region, he helped develop Glosten's proprietary software package *G-FORTE* – a comprehensive, physicsbased transportation model for ferry system optimization. He continues as *G-FORTE*'s lead

developer and has recently applied it to develop the concept design for a new Alaska ferry serving Ketchikan and Prince Rupert.

Drawing on his structural analysis experience at Glosten, Ben has contributed to two SNAME Transactions papers applying the concepts of statistical principal axis theory to structural fatigue and dynamic loads analysis.

Ben served as the analysis project manager for the design of the conversion of a bare deck semisubmersible platform to the Missile Defense Agency's Sea-based X-Band Radar (SBX) Platform. In addition to managing all the analysis tasks, he contributed directly to the structural design, seakeeping and operability analyses, an extensive resistance and seakeeping model test program, dynamic loads and finite element analyses, a comprehensive vibration analysis, and vibration isolation system design. He currently serves as Glosten's Program Manager for ongoing SBX Platform design and engineering support.

Papers:

Hutchison, Bruce. L., Ackers, Benjamin B., and Leach, Timothy S., "Principal Axes for Structural Fatigue," SNAME Transactions 113 (2005).

Ackers, Benjamin B., Hutchison, Bruce L. and Larsen, David W., "Optimizing Your Ferry System: Choosing the Right Vessel for the Right Route," Presented at Ferries 2005, Delray Beach, FL, November 2005.

Ackers, Benjamin B., Landen, Heidi C., Michael, Thad J. et al., "An Investigation of the Resistance Characteristics of Powered Trimaran Side-hull Configurations," SNAME Transactions 105 (1997

CHARLES J. NORDSTROM, PE

Occupation	**Naval Architect and Ocean Engineer**
Experience	2002 - Present The Glosten Associates, Inc. 2001 - 2002 University of Michigan, Graduate Student Research Assistant 2000 Herbert Engineering Corp., Intern Naval Architect
Education	MSE (2002) and BSE (2001), Naval Architecture and Marine Engineering, University of Michigan
Licensing / Certifications	PE (2006), Washington State, Naval Architecture and Marine EngineeringPMP (2007), Project Management Institute
Memberships	Society of Naval Architects and Marine Engineers Project Management Institute

EXPERTISE

Design and Analysis

- Purpose-Built Vessels
- Barges
- Special-Purpose Platforms
- Mooring Systems
- Marine Logistics
- Sea-Keeping and Maneuvering
- Dynamic Positioning
- Wave Loads and Motions Analysis
- Geographic Information Systems

Project Management

- Offshore Renewable Energy
- Environmental Footprint Reduction
- Ballast Water Management
- Maneuvering Sea Trials and Test Plans

Analysis Tools

- *WAMIT, SMP, Custom Programs*: Sea-Keeping and Maneuvering Analysis
- *AnySIM Pro, Custom Programs*: Dynamic-Positioning Analysis
- *FEMAP, NASTRAN*: Structural Design and Analysis
- *Optimoor*: Mooring Analysis and Design
- *ArcGIS*: Geographic Information Systems

Innovative New Tool Development

- *GEO Ballast* Shipboard Software
- In-House Dynamic Positioning Analysis Tools
- GIS-Based Applications

RELEVANT WORK EXPERIENCE

Charles Nordstrom joined The Glosten Associates in 2002 after completing both a Bachelor's and Master's degree in Naval Architecture at the University of Michigan.

Recently, Charles led the concept and preliminary design efforts for a Wind Turbine Installation Vessel that will be used to construct the first North American offshore wind farm. He also led marine logistics studies for two separate offshore wind farms, which resulted in owner's requirements for purpose built vessels, as well as fleet definition for chartered equipment. His recent analysis efforts include a time-domain, dynamic positioning study for a semi-submersible.

A number of Charles' projects have a key objective to reduce the environmental footprint of marine operations; e.g., the development of a greaseless jack up system, concept design of a dual-fuel tug boat, and evaluation of alternative methods for capturing and processing vessel smoke stack emissions. Charles led the software development project for *GEO Ballast,* which assists vessel operators with ballast water planning, management, and reporting.

As project engineer, Charles was responsible for the design and analysis of mooring systems for the Olmsted Dam catamaran barge and for the Hawaii Superferry shore landing barges.

Charles led the maneuvering sea trials for a 180,000 deadweight-ton oil tanker. He specified the test plan, attended
the trials to ensure proper execution of maneuvers, recorded and analyzed trials data, and prepared a final report to the
client. He also served as the project engineer for a wave loads and motions analysis of offshore liquid natural gas import terminals for the northeast United States.

Developing an in-house tool, Charles analyzed the steady-state DP (dynamic positioning) capabilities of a semi-submersible platform. He then led detailed analyses of the vessel using *AnySIM Pro*, a state-of-the-art, time-domain DP analysis suite, identifying existing capabilities and potential DP system upgrades.

Charles served as a project engineer for a comprehensive risk analysis of Puget Sound's tug-tanker escort system, identifying risk parameters, evaluating parametric trade-offs, and communicating study findings in a manner accessible to the general public.

As Glosten's lead geographic information systems (GIS) analyst, Charles has compiled project-specific maps and
nautical charts and has developed GIS-based software applications. He is trained in *ArcGIS,* and has used *Visual*
Basic.NET for software development.

Charles is an active member of the Society of Naval Architects and Marine Engineers. He is an advisor to the Oregon Wave Energy Trust, serving on the Research and Development Committee. He also volunteers with a local artist cooperative, designing rafts for an upcoming floating art installation.

KEN L. FITZGERALD

Occupation	**Senior Engineer**
Experience	1990 – 1996 Louisiana State University Coastal Studies Institute 1996 – 2003 Evans-Hamilton Oceanographers 2003 – present The Glosten Associates
Education	Texas A&M University Ocean Engineering Curriculum, 1987-89 Louisiana State University B.S., Petroleum Engineering, 1992 OSHA Hazardous Waste Operations Certification, August 2003
Licensing / Certifications	
Memberships	

RELEVANT WORK EXPERIENCE

Ken's time at Glosten has been devoted to marine logistics consulting for the offshore oil industry, management of oceanographic surveys, geophysical surveys and ship alterations to accommodate ballast water management systems and innovative oceanographic tools.

Ken was the project manager for the ship modifications project for the Woods Hole Oceanographic Institute's Long Core, a new deepwater marine sediment coring system. The Long Core project required extensive ship modifications to the R/V Knorr. Ken was also the project manager for anchor performance field testing for the Boeing SBX platform.

Ken has extensive field experience, including field management of marine geophysical surveys in support of mooring design for the Boeing SBX platform, field management for ROV survey and 3D modeling of hurricane damaged oil structures, and owners field representative for shipyard modifications to the Boeing SBX platform for heavy lift dry transport.

Ken has served as navigation and positioning technical specialist for maneuvering trials of a modified tanker ship and as a signals technical specialist for tanker ship ballast water monitoring system.

Ken joined The Glosten Associates after 13 years of varied engineering, design and project management experience, including:

- Serving as project manager of an ocean current circulation study of the entire coast of Nigeria funded by a consortium of oil companies for oil spill control.
- Performing project management of ocean current studies for design of oil rigs and spar structures in the Gulf of Mexico and offshore Angola.
- Providing project management for stream flow studies used in wetland management by the South Florida Waterways Management District.

- Solving engineering problems related to oceanographic data collection worldwide. Including engineering the design and construction of hydraulic cranes, A-frames, hydraulic winches, power packs and a submersible instrument barge.
- Working as cruise manager for oceanographic research cruises, including chartering and converting workboats for research, and planning cruise tracks to optimize time and expense.
- Managing data for numerous current meter deployments, hydrographic data sets, meteorological stations and tide gauge studies. This included programming to build data processing software and generating data reports and graphics for data utilization.
- Serving as deck crew chief for oceanographic mooring deployment and service cruises worldwide, with responsibility for safe recovery of moorings, diving operations, refit of workboats, and parts and supply acquisition in remote locations.
- Fabricating oceanographic tool designs and building and repairing hulls.
- Serving as field technician responsible for fabrication and deployment of inshore oceanographic platforms, offshore moorings, towed systems and hydrate mound gas meters.
- Conducting underwater salvage, searches and instrument deployments in a wide range of sea conditions

CHARLES L. MORGAN

Occupation	**Environmental Planner**
Experience	2000 - Present: Employer: Planning Solutions, Inc., Honolulu, HI Position: Environmental Planner Duties: Solicit, propose, and manage projects; draft permit applications & environmental documentation; GIS spatial analysis 1994 - 2000: Employer: Self employed; Hawai`i General Excise ID#10433825 Position: Independent Consultant Duties: Provide consultation to government and private parties in the fields of oceanographic survey and environmental impact assessment 1989 – 1999: Employer: Research Corporation of the University of Hawai`i Position: Associate Researcher, Hawai`i Natural Energy Institute Duties: Oceanographic & environmental science research 1984 – 1991: Employer: Research Corporation of the University of Hawai`i Position: State Project Coordinator Duties: Manage completion of a programmatic Environmental Impact Statement for the U.S. Department of the Interior 1975 – 1984: Employer: Lockheed Advanced Marine Systems, Sunnyvale & San Diego, California Positions: Senior Research Scientist, Associate Research Scientist Duties: Environmental assessment; laboratory design and operation; seabed exploration
Education	Ph.D., University of Wisconsin – Madison (1975); Major - Oceanography and Limnology; thesis comparative research on environmental chemistry of manganese nodules in Lake Michigan & the Pacific M.S., University of Wisconsin - Madison, December, Oceanography and Limnology (1973); Included M.S. course requirements in geology and graduate courses in ecology, botany and bacteriology B.A., University of California - San Diego (1971); Major - Chemistry
Licensing / Certifications	
Memberships	

Publications

[1] Jones, A.T. and C.L. Morgan. Code of Practice for Ocean Mining: An International Effort to Develop a Code for Environmental Management of Marine Mining. *Marine Georesources and Geotechnology*, 21(2):105-114, 2003.

[2] Morgan, C.L., Environmental Impact Assessment for Deep Sea Mining. In Offshore Mineral Wealth Policy: the Madang Guidelines. *South Pacific Geoscience Commission*, Suva, Fiji, 1999.

[3] Morgan, C.L., Important precedents for environmental impact analysis in the U.S. Exclusive Economic Zone. *Twelfth Annual Seminar: Ocean Mining Development and American Industry The Center for Oceans Law and Policy*, University of Virginia School of Law, Charlottesville, Virginia 10 p., 1988.

[4] Morgan, C.L. and F.T. Lovorn, Modeling the Coagulation of a Solids Waste Discharge From a Manganese Nodule Processing Plant. Invited Chapter In: *Wastes in the Ocean,* Dana Kester (ed.), Wyle & Sons, 1985.

[5] Morgan, C.L. The Hawaii manganese crust environmental impact statement: An example of modern environmental analysis.in *Pacific Mineral Resources Physical, Economic, and Legal Issues* C. J. Johnson and A. L. Clark (ed), East-West Center, Honolulu, Hawaii. p 449-459, 1985.

[6] Morgan, C.L. Environmental Impacts of Deep Ocean Mining The Importance of Manganese. Chapter 14 In: *Marine Environmental Pollution, 2. Dumping and Mining*, R.A. Geyer (ed.), Elsevier Scientific Publishing Co., Amsterdam, 1981.

[7] Morgan, C.L. The Environmental Impacts of Deep Seabed Mining An Industrial Approach. *United Nations Law of the Sea Treaty Negotiation Sessions*, New York and Geneva, 1979, 1980.

[8] Morgan, C.L. and F.T. Lovorn. At Sea Discharge of Ocean Mining Process Rejects; An Alternative to Land Disposal. *Offshore Technology Conference* (OTC No. 3451), Houston, Texas 1979.

Synergistic Activities

Ongoing: Permitting and Environmental Impact Analysis for Ocean Thermal Energy Conversion in Hawai'i, for Lockheed Martin Corporation

Ongoing: State of Hawai'i Permitting and visual impact analysis for a Wind Farm Expansion, Kaheawa, Maui

Ongoing: Permitting analysis for the Oceanlinx Wave Energy project, offshore Maui, Hawai'i
2007: EIS drafting, land use permitting for Hawaiian Electric Company 100 MWe Campbell Industrial Park Electrical Generating Station (under construction)

2002: EIS drafting, land use permitting for Hawaiian Electric Company 13-mi. petroleum pipeline, O`ahu, HI (in operation)

Principle Investigators

Frederick R. Driscoll
Associate Professor and Technical Director of the Center for Ocean Energy Technology
Department of Ocean Engineering, SeaTech Campus
101 North Beach Road, Dania Beach, FL, 330004
Tel. 954 924 7221
Fax. 954 924 7007
Email. rdriscol@oe.fau.edu

Education and Training

Ph.D., Mechanical Engineering and Ocean Physics, University of Victoria, Canada, 1999.

B.Eng., Mechanical Engineering with Coop and Business Management Options, University of Victoria, Canada, 1994 with Distinction.

Professional Experience

2007 – 2008	Technical Director, Center for Ocean Energy Technology, Florida Atlantic University
2007 – 2008	Commissioner, Florida Energy Commission, State of Florida
2000 – PRESENT	Associate Professor, Department of Ocean Engineering, Florida Atlantic University
1996 – 1999	President and CEO, Deep Sea Technologies Ltd., British Columbia, Canada.
1993	Pipeline Engineer, National Energy Board, Alberta, Canada.
1992	Reservoir/Production Engineer, Gulf Canada Resources, Alberta, Canada
1991	Reservoir Engineer, Mobil Oil Canada, Alberta, Canada

Publications

[1] F.R. Driscoll, S. Skemp, and G. M. Alsenas, 2008, "Florida's Center for Ocean Energy Technology", Proceedings of the MTS/IEEE Oceans Conference, Quebec, Canada, September 15-18.

[2] F.R. Driscoll, G. M. Alsenas, S. Ravenna, R., E. Busold, and C. Slezycki, 2008, "A 20 kW Open Ocean Current Test Turbine", Proceedings of the MTS/IEEE Oceans Conference, Quebec, Canada, September 15-18.

[3] J. VanZwieten, F.R. Driscoll, A. Leonessa, and G. Deane, In Press 2006, "Design of a Prototype Ocean Current Turbine Part I: Mathematical Modeling and Dynamics Simulation," *Ocean Engineering*, Vol. 33, 1485-1521.

[4] J. VanZwieten, F.R. Driscoll, A. Leonessa, and G. Deane, In Press 2006, "Design of a Prototype Ocean Current Turbine Part I: Flight Control System Development," *Ocean Engineering*, Vol. 33, 1522-1551.

[5] W. Venezia, W. Baxley, P. Tatro, M. Dhanak, F.R. Driscoll, P. Beaujean, S. Shock, S. Glegg, E. An, M. Luther, B. Weisberg, H. DeFerrari, N. Williams, H. Nguyen, N. Shay, J. Van Leer, R. Dodge, D. Gilliam, A. Soloviev, S. Pomponi, M. Crane, and K. Carter, 2003, "SFOMC, A Successful Navy And Academic Partnership Providing Sustained Ocean Observation Capabilities in the Florida Straits", *Marine Technology Society Journal*, Vol. 37, 81-91.

[6] R.E. Raye and F.R. Driscoll, 2002, " Inertial Correction of Ship-Mounted ADCP Records," *IEEE Oceanic Engineering Society Newsletter,* Vol. 38, 5-10.

[7] R. E. Raye, Characterization Study of the Florida Current at 79' 11'' North Latitude, 75' 50'' West Longitude for Ocean Current Power Generation, Masters Thesis (advisor)

[8] Project Aquantis: Report on SBIR Phase II Completion, Development of a Sustained Ocean Current-Driven Electric Power Generating System, Submitted to the US Department of Energy, 2003.

[9] Project Aquantis: Report on SBIR Phase I Completion, Development of a Sustained Ocean Current-Driven Electric Power Generating System, Submitted to the US Department of Energy, 2001.

Patents

"Underwater Payload Mooring System," Provisional patent (#. 60\888,418) and patent pending, 2007, F. R. Driscoll, P. P. Beaujean, and J. C. Frankenfield.

"Deployable and Autonomous Mooring System", 7,179,145, 2007, F. R. Driscoll, T. Pantelakis, C. Castanier, and W. Venezia.

Synergistic Activities

Supervisor for a masters thesis project entitled: "An Assessment of the Ocean Thermal Energy Potential offshore Southeast Florida"

Supervisor for a Ph.D. Dissertation entitled: "A Practical Assessment of the Producible Energy from the Florida Current off the Southeast Coast of Florida"

Principle Investigator for an Industry Sponsored project entitled "Ocean Thermal Resource Assessment and Location Trade Study for Lockheed Martin"

Principle Investigators

Desikan Bharathan

Phone: (303) 275-4613

Email: desikan.bharathan@nrel.gov

EDUCATION AND TRAINING

- B. Tech., Aeronautical Engineering, 1970, Indian Institute of Technology, Madras, India
- M.S., Aerospace Engineering, 1972, University of Virginia, Charlottesville, VA
- Ph.D., Aerospace Engineering, 1976, University of Virginia, Charlottesville, VA

PROFESSIONAL EXPERIENCE

Principal Engineer (Present):

- Design, develop and analyze of advanced power cycles using mixed working fluids.
- Model and analyze hybrid-powered vehicles, implement cooling power electronics
- Develop of advanced direct-contact condenser (ADCC) (licensed by Alstom Energy Systems Inc. and operating at three Calpine Units at the Geysers and other plants in Mexico).
- Develop numerical methods to model complex systems.
- Conduct research on direct-contact heat exchange for production and condensation of low-pressure steam for geothermal and ocean thermal energy systems.
- Manage and direct research and development team.
- Developed the open-cycle ocean thermal energy conversion facility in Kona, Hawaii that holds the world record for power production.
- Other research areas include: desiccant cooling/HVAC applications, high-performance variable conductance insulation, turbo machinery, and combustion modeling for burners in fiberglass manufacturing.

Professor, Thayer School of Engineering, Dartmouth College, NH (1976 to 1980):

- Taught complex variables and Fourier transforms.
- Conducted laboratory sessions in fluid mechanics.
- Conducted experimental and theoretical investigations of two-phase flow.
- Supervised graduate and undergraduate research.

Research Laboratories for Engineering Sciences, Univ. of Virginia, Charlottesville, VA (1970 to 1976):

Conducted research towards doctoral dissertation. Devised an innovative technique for measuring aerodynamic stability derivatives for missile-shaped models suspended magnetically in a wind tunnel. Investigated boundary layers on spinning cones in supersonic flow. Measured lift and drag coefficients on simple aerodynamic bodies submerged in hypersonic rarefied flows utilizing an electromagnetic suspension. Investigated glow-discharge visualization techniques for rarefied flow fields.

Indian Institute of Technology, Madras, India (1965 to 1970):

Evaluated performance of aniline and red-fuming nitric acid as rocket fuels. Conducted a preliminary design of a tilt-wing vertical take-off and landing aircraft.

Principle Investigators

PUBLICATIONS

Author of over 50 technical publications in refereed journals and over 40 technical reports in the areas of hypersonic flow, aerodynamics, aerodynamic stability of vehicles, low-temperature heat and mass transfer, two-phase flows, desiccant cooling, advanced high temperature insulation, power cycles using mixed working fluids.

PATENTS

Holds five patents on subjects, such as: flash evaporator for seawater, method for cooling tower analysis, solar/natural gas hybrid central receiver power system, advanced direct-contact condensers, and mixed-working fluid advanced power cycles.

SYNERGISTIC ACTIVITIES

Conduct research, design and development for renewable energy power systems and processes for production and manufacturing.

Expert in many areas including Fluid Mechanics, Turbulence, Heat Transfer, Two-Phase Flows, Aerothermodynamics, Hypersonic Flow, Rarefied Gas Dynamics, and Linear and Non-Linear Control Systems.

Developed **conceptual and preliminary design** of the net-power producing experiment (NPPE) for **open-cycle OTEC** experimental facility built in Natural Energy Laboratory of Hawaii Authority (NELHA). This facility holds the **world record** for the largest power production of about 120 kW from OTEC resources.

Possesses extensive experience in process modeling with ASPEN, Computational Fluid Dynamic (CFD) analyses using **ANSYS** and **FLUENT**, solid modeling software **ProEngineer**, and **SolidWorks** modeling and design of complex engineering systems.

Professional and Honorary Societies:

- American Institute of Chemical Engineers (AIChE),
- American Society of Mechanical Engineers (ASME), Fellow
- Sigma Xi
- Professional Engineer, State of Colorado
- Past Chairman, Solar Heat Transfer, AIChE
- Past Chairman, Ocean Energy, Solar Energy Division of ASME

Principle Investigators

Donna M. Heimiller
Telephone: (303) 275-4667
E-mail: donna.heimiller@nrel.gov

EDUCATION AND TRAINING:

M.S., FORESTRY, 1998, COLORADO STATE UNIVERSITY, FT. COLLINS, CO
B.S., NATURAL RESOURCES, 1993, UNIVERSITY OF MICHIGAN, ANN ARBOR, MI

PROFESSIONAL EXPERIENCE:

Geographic Information Systems (GIS)

Analysis:

- Performed renewable resource development suitability analyses for multiple renewable energy resources (solar, onshore wind, offshore wind, geothermal and biomass) based on resource level, proximity to infrastructure, proximity to load, and potential environmental conflicts.
- Processed wind resource data for use in national energy and market penetration models (REEDS/WinDS/CSDS and NEMS) to account for land availability, transmission line capacity, demand profiles and cost factors related to distance and resource level.
- Created tools and performed analysis to aid with renewable energy (wind, hydro, and solar) resource assessment, quality assessment and validation activities.

Databases:

- Created and maintained GIS databases of renewable energy resource. Most recently, built a combined GIS database of offshore wind power class, bathymetry, distance from shore, and administrative entity.
- Processed data from multiple scales and sources for use in standard GIS databases at NREL.

Programming:

- Developed extensions and Avenue scripts to extract data by geographic region, automate data screening, conduct analysis of meteorological data, and produce publication quality maps.
- Assisted with the development and modification of AMLs for the wind resource assessment model used at the National Renewable Energy Laboratory.

Other:

- Managed NREL's Geographic Information Systems Service Center, staffed by 6 employees with an annual operating budget of $850K.
- Trained and assisted staff at the National Renewable Energy Laboratory in the use of GIS software.
- Produced publication quality maps, tables and other graphic outputs.

NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN, CO JUNE 1997 – PRESENT

Senior Scientist I (GIS): Identified potential renewable resource areas (wind, solar, biomass, geothermal and micro-hydro), criteria impacting renewable resource development (i.e. transmission availability), and produced publication quality graphics.

COLORADO STATE UNIVERSITY, FORT COLLINS, CO AUGUST 1997–DECEMBER 1997

Teaching Assistant: Instructed students in an undergraduate level introductory GIS course in the use of Idrisi and pcArc/Info to conduct spatial analyses.

SELECTED PUBLICATIONS

1. Heimiller, D.; Haymes, S.; Schwartz, M.; Musial, W. (2008 draft). Assessment of Offshore Wind Energy Resources for the United States Using a Standard Geographic Information Systems Database. Prepared for the Department of Energy by the National Renewable Energy Laboratory.
2. Heimiller, D.; Renne, D.; Stoffel, T.; Brown, E. (2007). Report to Congress on Renewable Energy Resource Assessment Information for the United States. 95 pp.
3. Walker, A.; Kandt, A.; Heimiller, D. (2006). "Wave Power for U.S. Coast Guard First District Lighthouses". (ISEC2005-76105). Solar Engineering 2005: Proceedings of the 2005 International Solar Energy Conference (ISEC2005), 6-12 August 2005, Orlando, Florida. New York: American Society of Mechanical Engineers (ASME) pp. 573-580; NREL Report No: CP-710-37767.
4. Blair, N.; Short, W.; Denholm, P.; Heimiller, D. (2006). Long-Term National Impacts of State-Level Policies. 20 pp.; NREL Report No. CP-620-40105.
5. Assessing the Potential for Renewable Energy on National Forest System Lands. (2005). 123 pp.; NREL Report No. BK-710-36759.
6. Short, W.; Blair, N.; Heimiller, D. (2005). "Modeling the Market Potential of Hydrogen from Wind and Competing Sources". Windpower 2005 Conference and Exhibition.
7. Farhar, B.; Heimiller, D. (2003). Opportunities for Near-Term Geothermal Development in the Western United States. ; NICH Report No. 32581.
8. Elliott, D.; Schwartz, M.; Scott, G.; Haymes, S.; Heimiller, D.; George, R. (2003). Wind Energy Resource Atlas of Sri Lanka and the Maldives. 175 pp.; NICH Report No. TP-500-34518.
9. Heimiller, D. M.; Haymes, S. R. (2001). "Geographic Information Systems in Support of Wind Energy Activities at NREL: Preprint". 10 pp.; NICH Report No. CP-500-29164. Presented at the 2001 ASME Wind Energy Symposium.
10. Heimiller, D. and Dean, D. (1998). "Optimizing Placement of Prescribed Burns to Maximize Wildfire Burn Times to Points of Value in the Wildland/Urban Interface Zone". Presented at the 1998 Southern Forestry and GIS Conference

SYNERGISTIC ACTIVITIES

- 11 years experience at NREL, working on multiple renewable technologies
- 4 years as the technical lead for GIS activities at NREL
- Over 40 technical publications
- Formally educated in Geographic Information Systems

Principle Investigators

Robert J. Howard
Senior System Architect
Lockheed Martin Corporation MS 120/026
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Manassas, Va 20110-4157
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Fax. 703 367 5597
Email. robert.j.howard@lmco.com

Education and Training

Whitworth College, B.S., Physics/Mathematics	1970
Brigham Young University, 5 Sem., Graduate Physics	1975-76
M.S. Applied Physics, George Mason University, Fairfax, VA,	1992

Professional Experience

Lockheed Martin, Marine Systems and Sensors, 2001 to Date **Senior Systems Architect**

Participated in development of OTEC designs, components and environmental assessments. Development of ocean acoustic and environmental modeling and simulation. Development of sonar systems, sonar, software production and algorithm development / testing.

Analysis and Technology, Inc. 1983-2000 **Corporate Scientist**

System engineering. Sonar sensor system and simulation design, development, testing and review. Performance of ocean acoustic and environmental modeling. Acoustic signal processing.

Hydrotronics Inc. 1977-1983 **Senior Technical Specialist**

Sonar system performance analysis. Sonar trainer evaluations, design reviews.

U.S. Navy 1970-1975 **Nuclear Qualified Line Officer**

Operation, supervision and maintenance of Naval nuclear power plant.

Publications

Pending Patents (not yet published by PTO)

1. Ascari, Matthew B. , Howard, Robert J. , Rapp, John W. , Ocean Thermal Buoyancy Propulsion on Thermo-Dynamic Cycle, pending
2. Howard, Robert J. , OTEC Cold Water Pipe Stress Relief, pending
3. Howard, Robert J , Rapp, John W, Ocean Thermal Energy Conversion (OTEC) Powered Unmanned Undersea Vehicle (UUV) Power Supply, pending

4. Howard, Robert J, Meyer, Laurie E, Rapp, John W, Nagurny, John, Ocean Thermal Energy Conversion (OTEC) Implementation and Methods using Bulk Thermal Media Transport,, pending
5. Howard, Robert J, Rapp, John W, Meyer, Laurie E, Nagurny, John. ,Submersible OTEC Plant, pending

Patents (Published – not yet issued)

- 20080314043, *Howard*; Robert J.; *(Clifton, VA)* ; Rapp; John W.; *(Manassas, VA)* ; Grandelli; Patrick; *(Kailua, HI)* ; Van Ryzin; Joseph C.; *(Kailua, HI),* CLATHRATE ICE THERMAL TRANSPORT FOR OCEAN THERMAL ENERGY CONVERSION, December 25, 2008
- 20080295517, *Howard*; Robert J.; *(Clifton, VA)* ; Rapp; John W.; *(Manassas, VA),* EXTRACTION OF NOBLE GASES FROM OCEAN OR SEA WATER, December 4, 2008

Synergistic Activities

- OTEC system and component design studies and evaluations
- OTEC resource estimates
- OTEC risk assessments
- OTEC environmental risk identification and evaluations
- OTEC OpCon development

Principle Investigators

James T. Potemra

Telephone: (808) 956-2737
E-mail: jimp@hawaii.edu

Education and Training

B.S., 1986, Physics, Stevens Institute of Technology, Hoboken, NJ
M.S., 1990, Oceanography, Florida State University, Tallahassee, FL
PhD, 1998, Oceanography, University of Hawaii, Honolulu, HI

Professional Experience

2008 – PRESENT	Faculty, Hawaii Institute of Geophysics and Planetology (HIGP), University of Hawaii, Honolulu, HI
2008 – PRESENT	co-manager, Asia-Pacific Data-Research Center (APDRC), IPRC/SOEST, University of Hawaii, Honolulu, HI
2001 – 2008	Assistant Researcher, IPRC/SOEST, University of Hawaii, Honolulu, HI
1999 – 2001	Research Associate, post-doctoral, University of Washington, Seattle, WA
1998 – 1999	Post-doctoral researcher, IPRC/SOEST, University of Hawaii, Honolulu, HI

Publications

[1] Cornillon, P., J. Adams, M. B. Blumenthal, E. Chassignet, E. Davis, S. Hankin, J. Kinter, R. Mendelssohn, J. T. Potemra, A. Srinivasan and J. Sirot 2009: NVODS and the development of OPeNDAP - an integrative tool for oceanographic data systems. *Oceanography*, in press.

[2] Potemra, J. T. and T. Qu 2009: The Seas of Southeast Asia. Encyclopedia of Ocean Sciences, 2nd Edition, J. H. Steele, K. K. Turekian and S. A. Thorpe, Editors. Oxford: Academic Press.

[3] Jochum, M. and J. T. Potemra 2008: Sensitivity of tropical rainfall to Banda Sea diffusivity in the Community Climate System Model. *J. Climate*, **21**, 6,445--6,454.

[4] Potemra, J. T. and N. Schneider 2007: Influence of low-frequency Indonesian throughflow transport on temperatures in the Indian Ocean in a coupled model. *J. Climate*, **20**, 1,339--1,352.

[5] Yu, Z. and J. T. Potemra 2006: Generation mechanism for the intraseasonal variability in the Indo-Australian basin. *J. Geophys. Res.*, **111**, C01013, doi:10.1029/2005JC003023.

[6] Potemra, J. T., J. Sprintall, S. L. Hautala and W. Pandoe 2003: Observed estimates of convergence in the Savu Sea, Indonesia. *J. Geophys. Res.*, **108**(C1), 3001, doi:10.1029/2002JC001507.

[7] Annamalai, H., R. Murtugudde, J. T. Potemra, S. P. Xie, P. Liu and B. Wang 2003: Coupled Dynamics in the Indian Ocean: Externally or Internally Forced? *Deep Sea Res. II*, **50**, 2,305--2,330.

[8] Potemra, J. T., S. L. Hautala, J. Sprintall, and W. Pandoe 2002: Interaction between the Indonesian seas and the Indian Ocean in observations and numerical models. *J. Phys. Ocean.*, **32**, 1,838--1,854.

[9] Potemra, J. T., 2001: Contribution of equatorial Pacific winds to southern tropical Indian Ocean Rossby waves. *J. Geophys. Res.*, **106**, 2,407--2,422.

[10] Potemra, J. T. and R. Lukas, 1999: Seasonal to interannual modes of sea level variability in the western Pacific and eastern Indian Oceans. *Geophys. Res. Let.*, **26**, 365-368.

Synergistic Activities

Co-ordinator of Pacific Regional Argo Center
Member of Pacific Island Global Ocean Observing System (PI-GOOS) advisory committee
Member of Integrated Ocean Observing System (IOOS) Data Integration Framework working group
Adjunct faculty, Dynamic Physical Oceanography, MARS-3080, Hawaii Pacific University

Principle Investigators

George Scott

Telephone: (303) 384-6903
E-mail: george.scott@nrel.gov

EDUCATION AND TRAINING:

M.S., Geophysics, 1982, University of Michigan
B.S., Mathematics, 1975, University of Michigan
B.S., Geology, 1975, University of Michigan
Graduate-level courses in signal and image processing, University of Colorado

PROFESSIONAL EXPERIENCE:

NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN CO ***1985 – PRESENT***

Scientist ***1995 - Present***

- *Support wind resource assessment with data analysis, writing reports and atlases, site visits and training, etc.*
- *Support scientific projects (e.g. turbulence analysis) with data visualization, mathematical and statistical analysis, and programming*
- *Support Wind Powering America project with data management tasks*

Research Data Applications Programmer ***1985 – 1995***

- *Support wind turbine data analysis with flow visualization and data analysis programs*
- *Support turbulence analysis projects*
- *Conversion of large data processing program to run on NREL's computers*

SUPERIOR OIL COMPANY, HOUSTON, TX ***1982 – 1985***

- *Develop techniques and software for seismic exploration*

SELECTED PUBLICATIONS:

1. Schwartz, M., Elliott, D., Scott, G., 2007, Coastal and Marine Tall-Tower Data Analysis: Preprint.
2. Kelley, N. D., Jonkman, B. J., Scott, G. N., 2006, Great Plains Turbulence Environment: Its Origins, Impact, and Simulation,(Proceedings of) Windpower 2006 Conference and Exhibition (CD-ROM, Technical Track), 4-7 June 2006, Pittsburgh, Pennsylvania,Washington, DC: American Wind Energy Association
3. Kelley, N. D., Jonkman, B. J., Bialasiewicz, J. T., Scott, G. N., Redmond, L. S., 2005, Impact of Coherent Turbulence on Wind Turbine Aeroelastic Response and its Simulation,Windpower 2005 (Windpower 05) Conference and Exhibition (CD-ROM), 15-18 May 2005, Denver, Colorado,Washington, DC: American Wind Energy Association, Content Management Corp.
4. Elliott, D., Schwartz, M., Scott, G., 2004, Wind Resource Base,Encyclopedia of Energy,Elsevier Inc.
5. Elliott, D., Schwartz, M., Scott, G., Haymes, S., Heimiller, D., George, R., 2004, Atlas de Recursos Eolicos del Estado de Oaxaca, (The Spanish version of Wind Energy Resource Atlas of Oaxaca)

6. Elliott, D., Schwartz, M., Scott, G., Haymes, S., Heimiller, D., George, R., 2003, Wind and Solar Resource Assessment of Sri Lanka and the Maldives (CD-ROM)
7. Elliott, D., Schwartz, M., Scott, G., Haymes, S., Heimiller, D., George, R., 2003 ,Wind Energy Resource Atlas of Armenia.
8. Elliott, D., Schwartz, M., Scott, G., Haymes, S., Heimiller, D., George, R., 2003, Wind Energy Resource Atlas of Oaxaca.
9. Elliott, D., Schwartz, M., Scott, G., Haymes, S., Heimiller, D., George, R., 2002, Wind Energy Resource Atlas of Southeast China.
10. Elliott, D., Schwartz, M., George, R., Haymes, S., Heimiller, D., Scott, G., Kline, J., 2001, Wind Energy Resource Atlas of the Dominican Republic.

SYNERGISTIC ACTIVITIES:

Lead data analyst for the wind resource assessment group at the NREL.

- Helped to prepare updated wind resource maps for U.S. states and selected foreign regions and countries. Worked with Geographic Information System staff to integrate wind resource data into GIS
- Wrote software for validating state resource maps produced using mesoscale numerical modeling technique.
- Provide technical support to Wind Powering America Program and DOE Headquarter wind resource information requests
- Helped write and prepare wind resource atlases for USAID projects.
- Maintain databases and software for all wind resource data sets.

Wind energy forecasting work:

- Developed guidelines for tall tower instrumentation and measurement

Technical support for offshore wind resource assessment

- Assisting in effort to map, and validate wind resource for offshore areas of the United States. Will help design methodology to quantify offshore wind resource potential.

Technical support for wave energy resource assessment

- Develop quality-control and validation methods for data from wave energy models. Help define data formats for integrating wave data into NREL's GIS.

Key Personnel

Howard P. Hanson
Professor of Geosciences and Scientific Director of the Center for Ocean Energy Technology
Florida Atlantic University
777 Glades Rd., Boca Raton, FL 33431
Tel. 561 297 2460
Email: hphanson@fau.edu

Education and Training

Ph.D., Graduate Program in Meteorology and Physical Oceanography, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 1979.

B.Sci., Aerospace Engineering, University of Illinois, 1972, with High Honors.

Professional Experience

2009 – present	Scientific Director, Center for Ocean Energy Technology, Florida Atlantic University
2005 – present	Professor of Geosciences (tenured), Department of Geosciences, Florida Atlantic University
2005 – 2009	Associate Vice President for Research, Division of Research, Florida Atlantic University
1997 – 2005	(2002 – 2005) Authorized Derivative Classifier, (1997 – 2005) Technical Staff Member, Los Alamos National Laboratory, University of California
2002 – 2005	Laboratory Directed Research and Development Program Office, Science and Technology Base Programs, University of California
1997 – 2002	Group Leader, Atmospheric and Climate Sciences, Earth and Environmental Sciences Division, University of California
1986 – 1997	(1993 – 1997) Executive Associate Director, (1986 – 1997) Fellow, Cooperative Institute for Research in Environmental Sciences, University of Colorado
1991 -1993	Associate Director, Educational and Scientific Programs, University of Colorado
1985 – 1997	(1991 – 1997) Senior Research Associate, (1985 – 1991) Associate Director, (1981 – 1991) Research Associate, Atmospheric and Climate Dynamics, University of Colorado
1979 – 1981	Resident Research Associate in residence at the NOAA Atlantic Oceanographic and Meteorological Laboratory, National Research Council/National Academy of Sciences

Key Personnel

Publications

[1] Hanson, H.P, 2009: Diversified renewables: The energy portfolio of the future. EnergyBiz, in press.

[2] Elliott, S.M., and H.P. Hanson, 2003: Syndication of the earth system: The future of geoscience? Environmental Science and Policy 6, 457-463.

[3] Elliott, S., K.S. Lackner, H.J. Ziock, M.K. Dubey, H.P. Hanson, S. Barr, N.A. Ciszkowski, and D.R. Blake, 2001: Compensation of atmospheric CO2 buildup through engineered chemical sinkage. Geophysical Research Letters, 28, 1235-1238.

[4] Hanson, H.P., M.M. Bradley, J.E. Bossert, R.R. Linn, and L.W. Younker, 2000: The potential and promise of physics-based wildfire simulation. Environmental Science and Policy, 3, 161-172.

[5] Elliott, S., D.R. Blake, H.P. Hanson, and F.S. Rowland, 1999: Fueling Asian modernization. Environmental Science and Policy, 2, 1-4.

[6] Hanson, H.P., C.S. Hanson, and B.H. Yoo, 1992: Recent Great Lakes ice trends. Bulletin of the American Meteorological Society, 73, 577-584 (w/ cover).

[7] Hanson, H.P., 1991: Air-sea interaction. In: Encyclopedia of Earth Systems Science, Volume 1, W. A. Nierenberg, Ed., Academic Press, San Diego, 61-69.

[8] Hanson, H.P., P. Cornillon, G. Halliwell, and V. Halliwell, 1991: Climatological perspectives, oceanographic and meteorological, on variability in the Northwest Atlantic. Journal of Geophysical Research (C), 96, 8517-8529.

[9] Hanson, H.P., 1991: Marine stratocumulus climatologies. International Journal of Climatology, 11, 147-164.

[10] Hanson, H.P., and B. Long, 1985: Climatology of cyclogenesis over the East China Sea. Monthly Weather Review, 113, 697-707.

Synergistic Activities

2007 - present: Principal Editor, Environmental Management & Policy Domain, TheScientificWorld

2005 - present: Editorial Board & Topic Editor for Air Pollution & Air Quality; Climate Change, Encyclopedia of Earth

2004 - present: Associate Editor, Environmental Science & Policy

2001 - 2002: Focus Leader, Planetary Atmospheres & Oceans, Institute for Geophysics and Planetary Physics, Los Alamos National Laboratory

1998 - 2002: Steering Committee, Atmospheric Science Programs, DOE Office of Science

Key Personnel

Anna Leland
101 N. Beach Rd Dania Beach, FL 33004 · (561) 262-9957
Email: anna.e.leland@gmail.com · aleland@fau.edu

Education and Training

2008-Present **Florida Atlantic University**
Masters of Science, Ocean Engineering and Minor in Business
Expected Graduation Date: December 2009

2003-2008 **Florida Atlantic University**
Bachelors of Science, Ocean Engineering

Professional Experience

2008-Present **Florida Atlantic University** Dania Beach, FL
Graduate Research Assistant
My thesis work is focused on performing a resource assessment for Ocean Thermal Energy Conversion applications off the coast of Southeast Florida. This work involves obtaining a time series of temperature data to determine energy production potential in relation to existing and future energy demand in South Florida, recommendations on plant siting, and analysis of the ocean and water property dynamics resulting from the extraction of ocean thermal energy.

2007-2008 **Florida Atlantic University's Center for Ocean Energy Technology** Dania Beach, FL
Undergraduate Research Assistant
I aided in assembly and fabrication of deep water ocean current turbine mooring system.

2006 **Harbor Branch Oceanographic Institution** Fort Pierce, FL
Summer Intern
As an intern, I assisted with the design of a deep-sea whole-water sampling system using AutoCad Inventor for use on HBOI's High Intake Defined Excitation Bathyphotometer that allowed for a more accurate study of bioluminescent organisms.

2001-2004 **Anderson-Moore Construction Corporation** Lake Park, FL
Administrative Assistant
During high school, I was an administrative assistant for a commercial general contracting company.

Publications

Driscoll, F.R., Skemp, S.H., Alsenas, G.M., Coley, C.J., and Leland, A.E. (2008) "Florida's Center for Ocean Energy Technology" in proceedings of the IEEE Oceans Conference, Quebec City, Quebec, September 15-18, No. 080523-023.

Key Personnel

Laura J. Martel

Telephone: (703) 629-7537
E-mail: laura.martel@lmco.com

Education and Training

B.S., Ocean Engineering, 1999, Florida Atlantic University, Boca Raton, FL
M.Eng., Acoustics, 2007, Pennsylvania State University, State College, PA

Professional Experience

1999 – PRESENT Engineer, Lockheed Martin MS2, Manassas, VA

- OTEC Program Manager
  Proposal management
- International Submarines New Business Technical Lead
  New business/proposal technical support and guidance for international submarine opportunities
- Technical Director S-80 Spanish Submarine Integrated Core Combat System
  Technical leadership for 70+ person team and coordination of international co-development
- Systems Engineer S-80 Spanish Submarine Combat System Proposal
  Key technical author and technical negotiator
- Key IRAD Investigator Underwater Weapon and Large Aperture Bow Array
  Underwater gun application analysis
  Acoustic environment analysis and sonar performance model development
- Lead Engineer/Deputy Program Manager Victoria Submarine Naval Combat Operator Trainer and Victoria Class Submarine Unique Trainer
  Cost, schedule and technical performance management
- Test Director Victoria Submarine Fire Control System
  Test program oversight and direction
  Delegated to serve as the customer witness during phase one system sell-off
- Lead Systems Engineer Victoria Submarine Fire Control System
  Requirements management from program inception through Critical Design Review

Publications

[1] M. Flicker, L. Martel, D. Ohlms, R. Varley, "Large Aperture Bow Array as Replacement for the Sphere Array," Proceedings of the 2004 Submarine Technology Symposium, Laurel, MD, May 11-13, 2004.

[2] M. Flicker, L. Martel, D. Ohlms, R. Varley, "Large Aperture Bow Array Performance Analysis," Presented at the 2004 Joint Undersea Warfare Technology Spring Conference, Monterey, CA, March 15-18, 2004.

[3] P. Ananthakrishnan, L. Martel, "Simulation of AUV motion in shallow water," Proceedings of the Oceans Community Conference'98, Baltimore, 1998.

Synergistic Activities

Program Manager Development Program - in progress
Engineering Leadership Development Program Graduate 12/2002
Manassas Leadership Development Program Graduate 10/2001

Key Personnel

Walter David Musial

Telephone: (303) 384-6956
E-mail: walter.musial@nrel.gov

EDUCATION AND TRAINING

B.S., Mechanical Engineering, 1980, University of Massachusetts, Amherst MA
M.S., Mechanical Engineering, 1983, University of Massachusetts, Amherst MA

PROFESSIONAL EXPERIENCE

NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN CO ***AUGUST 1988 – PRESENT***

NREL Laboratory Lead for Marine Renewable Energy ***2006 - Present***

- *Responsible for all Marine Energy Activities at NREL.*
- *Serves the International Energy Agency's Ocean Energy Systems Executive Committee (Alternate Delegate and IPCC Working Group 3, Climate Change Mitigation Committee.*
- *Organizer of the US Technical Advisory Group for the International Electro-technical Commission's Technical Committee 114 on Ocean Energy Systems.*

NREL Laboratory Lead for Offshore Wind Energy ***2002 – Present***

- *Responsible for all Offshore Wind Energy Activities at NREL, DOE program planning and reporting.*
- *Serves as Operating Agent for the International Energy Agency's Annex 23 on Offshore Wind.*
- *NREL's primary point of contact for offshore wind.*

Development Testing Team Leader ***1996 – 2002***

- *Served as Team Leader for Development Testing with up to15 permanent members for six years.*
- *Managed all facility issues in the Industrial User Facility at the National Wind Technology Center and defined and implemented requirements for staff, office, lab, security, safety, and facilities.*
- *Managed all testing for the DOE Wind Program in support of turbine research and industry product support and component certification.*

Test Engineer ***1988 – 2003***

- *Responsible for construction planning, oversight, and operation of all major NREL testing facilities.*
- *Developed NREL's blade test capability and conducted over 100 blade tests.*
- *Developed the first facility in the world to perform R&D testing on wind turbine drivetrains*
- *Served as technical chairman for the ASME Wind Energy Symposium for five years, which is the leading technical forum for peer reviewed wind energy technical exchange.*
- *Served on IEC/TC 88 working group 8 and developed the first set of internationally recognized blade testing guidelines from 1994 to 1999.*
- *Co-founded the AGMA/AWEA committee on wind turbine gear standards and served on it from 1994 to 2003 to produce the first internationally recognized standard for wind turbine drive trains.*
- *Served as lead test engineer for Phase 1 and 2 of the Unsteady Aerodynamics Experiment.*

U.S WINDPOWER/KENETECH WINDPOWER, LIVERMORE, CA ***APRIL 1986 – AUGUST 1988***

Mechanical Engineer: Responsible for all product support issues for over 4,000 USW 56-100 100-kW wind turbine installations.

ESI INC. DUBLIN, CA ***JANUARY 1984 – APRIL 1986***

Test Engineer: Conducted all phases of research and development testing and data analysis on the ESI-54 and the ESI-80 wind turbines.

Key Personnel

SELECTED PUBLICATIONS

1. Musial, W.D., Butterfield, C.P. and McNiff, B. "Improving Gearbox Reliability", European Wind Energy Association Proceedings, Milan, IT, May 2007.
2. Musial, W. D., *"Offshore Wind: Viable Option for Coastal Regions of the United States"*. Marine Technology Society Journal, Published Fall 2007.
3. Musial, W.D., Butterfield C.P. and, Ram, B. "Energy from Offshore Wind" Offshore Technology Conference Proceedings, Houston TX May 2006. (Best Paper Award)
4. White, D. and Musial, W.D. , ASME, Journal of Solar Energy Engineering "The Effect Of Load Phase Angle On Wind Turbine Blade Fatigue Damage", November 2004 (best paper in AIAA Wind symposium).
5. Musial, W.D., Butterfield, C.P. And Boone, A., "Feasibility Of Floating Platform Systems For Wind Turbines", AIAA-2004-1007, January 2004.
6. Musial, W. D.; Bourne, B.; Hughes, S. D.; Zuteck, M. D. (2001). Four-Point Bending Strength Testing of Pultruded Fiberglass Composite Wind Turbine Blade Sections. 15 pp.; NICH Report No. CP-500-30565.
7. Musial, W.; Freebury, G. (2000). "Determining Equivalent Damage Loading for Full-Scale Wind Turbine Blade Fatigue Tests". 12 pp.; Reno, Nevada. American Institute of Aeronautics and Astronautics Proceedings; NICH Report No. CP-500-27510.
8. Musial, W.; McNiff, B. "Wind Turbine Testing in the NREL Dynamometer Test Bed". Proceedings of American Wind Energy Association, Windpower 2000, Palm Springs, May 2000; 12 pp.; NICH Report No. CP-500-28411.
9. Musial, W. D.; McNiff, B. P.; Errichello, R. "Variations in Gear Fatigue Life for Different Wind Turbine Braking Strategies". 8 pp.; Proceedings of American Wind Energy Conference, Washington DC, Sept 1990 NICH Report No. TP-257-3984.
10. Musial, W. D.; Butterfield, C. P.; Jenks, M. D. (1990). "Comparison of Two- and Three-Dimensional S809 Airfoil Properties for Rough and Smooth HAWT Rotor Operation". 8 pp.; NICH Report No. TP-257-3603.

PATENTS

- ***NREL's Linear Hydraulic Blade Resonance Excitation*** *method for testing large wind turbine blade currently used by NREL, NaREC, and CENER.*

SYNERGISTIC ACTIVITIES

- *Internationally recognized expert in* ***Wind Energy*** *with over 25 years experience*
- *21 years experience at NREL*
- *6 years management and leadership experience as Team Leader at NREL*
- *Leader of offshore renewable energy projects including* ***Ocean Energy and Offshore Wind***
- *Demonstrated communication skills including media and government contacts*
- *5 years of wind industry industry-based field experience*
- *Over 40 technical publications.*
- *Formally educated in renewable energy and wind energy engineering.*

Key Personnel

Richard E. Rocheleau
Hawaii Natural Energy Institue (HNEI)
School of Ocean and Earth Science and Technology
University of Hawai'i
1680 East-West Road, POST 109
Honolulu, HI 96822

Education and Training

Ph.D. 1980: University of Delaware, Newark, DE.

M.S. 1977: University of Hawaii, Honolulu, HI.

BChE. 1973: University of Delaware, Newark, DE..

Professional Experience

2002 - PRESENT	Director, Hawaii Natural Energy Institute, SOEST, University of Hawaii
2000-2002	Interim Director, HNEI, SOEST, University of Hawaii
1990 – Present	Cooperating Graduate Faculty, Department of Mechanical Engineering, UH
1989- Present	Cooperating Graduate Faculty, Department of Electrical Engineering, UH
1997 – 1999	Researcher, Hawaii Natural Energy Institute, UH
1988 – 1997	Associate Researcher, Hawaii Natural Energy Institute, UH
1986 – 1988	Manager, Reactor Design, Institute of Energy Conversion Univ of DE
1980 – 1986	Engineer, Institute of Energy Conversion, Univ of DE
1977 – 1980	Research Assistant, Dept. of Chemical Engineering, Univ of DE
1975 – 1977	Research Assistant, Dept. of Ocean Engineering, Univ of HI
1973 – 1975	Engineer, Mobil Research and Development Corporation, NJ

Representative Publications

Bender G., K. Bethune, M. Angelo, S. Dorn, R. E. Rocheleau, 2009 "*Low Level Impurity Testing for Direct Hydrogen Polymer Electrolyte Fuel Cells" submitted to Journal of Power Sources* , May 2009

G. Bender, K. Bethune, M. Angelo, S. Dorn, T. Thampan, R. Rocheleau, 2009 "*Method Using Gas Chromatography to Determine the Molar Flow Balance for Proton Exchange Membrane Fuel Cells Exposed to Impurities*" accepted Journal of Power Sources, May 2009

Key Personnel

Hashimasa, Y, N. Yoshima, D. Ebata, H. Tomioka, M. Akai, S. Watanabe, K. Bethune, R. Rocheleau, 2007 "*Study of Performance Reproducibility of JARI Single Cell- Cell Crosscheck between HNEI and JARI*", JARI Research Journal, 29(1), pp 43-48, 2007

Marsen, B., E. Miller, D. Paluselli, R. Rocheleau,2007 *"Progress in Sputtered Tungsten Trioxide for Photoelectrode Applications"*, International Journal of Hydrogen Energy, 32,3110-3115 (2007)

Marsillac, S., S.Dorn, R.Rocheleau, E.Miller, 2004 "Low Temperature Deposition of Cu(InGa)Se2 Solar Cells on Various Substrates", Solar Energy Materials and Solar Cells, 2004, 82(1-2) 45-52.

Zidan, R. and R. E. Rocheleau,1999 "Thermodynamic Characterization of Hydrogen Interaction with Polyhydride Iridium Complex" J. of Materials Research, 14(1), 1999.

Synergistic Activities

Dr. Rocheleau has served as Director of HNEI since 2002. In addition to his personal research activities in the areas of thin film photovoltaics, renewable hydrogen technologies and fuel cells, Dr. Rocheleau has led several successful efforts to develop highly leveraged public-private partnerships addressing deployment, validation, and implementation of emerging renewable technologies. In recognition of this, in 2006, the Hawaii State legislature established HNEI in statute and expanded its mandate to include energy efficiency and assistance to the state to accelerate the acceptance of near-term commercial technologies. Major partnership initiatives led by Dr. Rocheleau include currently underway or in final negotiation include:

- Hawaii National Marine Renewable Energy Test Center – A DOE funded program to accelerate development and deployment of wave and ocean thermal energy conversion technologies.

- Hawaii Energy and Environmental Initiative - An ONR funded industry partnership with efforts in development and testing of fuel cells, characterization and use of methane hydrates, support of OTEC heat exchanger testing, and development and characterization of biofuels

- Hawaii Hydrogen Power Park - a partnership involving US DOE, US DOT, and US DOI, industry, and the state of Hawaii to establish clean hydrogen transportation systems at Volcano National Park;

- Hawaii Hydrogen Capital Investment Fund – a partnership with Kolohala Holdings to manage the $ 8.7 million Hydrogen Capital Investment Fund to accelerate implementation of hydrogen systems in Hawaii;

- Hawaii Distributed Energy Technologies for Energy Security - A US DOE funded partnership with the local electric utility and GE Global Research Center to facilitate high penetration of renewable energy systems onto the island grid systems

Key Personnel

Marc Schwartz

Telephone: (303) 384-6936
E-mail: marc.schwartz@nrel.gov

EDUCATION AND TRAINING:

B.S. Atmospheric Science, Cornell University 1975
M.S. Meteorology, Pennsylvania State University 1980

PROFESSIONAL EXPERIENCE:

NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN CO ***1994 – PRESENT***

Lead meteorological analyst for the wind resource assessment group

- Technical lead for preparing updated wind resource maps for U.S. states and selected foreign regions and countries. Closely work with Geographic Information System staff.
- Lead for validating state resource maps produced using mesoscale numerical modeling technique.
- Provide technical support to Wind Powering America Program and DOE Headquarter wind resource information requests
- Helped write and prepare wind resource atlases for USAID projects.
- Technical monitor for development of "Wind Resource Assessment Handbook"

Wind energy forecasting work:

- Lead NREL technical staff person to International Energy Agency Annex XI programs.
- Worked with AWS Scientific Inc. to provide background material on the needs of utilities for wind energy forecasting.
- Working with NOAA/Forecast Systems Laboratory on aspects of forecasting research.
- Provided support to of Electric Power Research Institute's (EPRI) Texas and California forecasting project.
- On the review panel EPRI/ California Independent Systems Operators wind forecasting project

Lead for Tall Tower Support subtask

- Process and analyze publicly available tall tower (80 m- 100 m+) wind measurement data
- Helped developed guidelines for tall tower instrumentation and measurement

Technical leader for offshore wind resource assessment

- Leading effort to map, and validate wind resource for offshore areas of the United States. Will help design methodology to quantify offshore wind resource potential. Involved in investigating wind characteristics for marine boundary layer.

Technical lead for Nevada Earmark wind projects

- Work with NREL staff and Desert Research Institute staff on the wind energy resource assessment projects funded by the Nevada Earmark

PACIFIC NORTHWEST LABORATORY ***1980 – 1994***

Wind Resource Assessment Analyst for Wind Group **1992-1994**

- Participated in several wind mapping activities including those for Mexico and Poland.
- Helped design the wind measurement analysis software still used by the wind resource group here at NREL to the present day.

Weather forecaster for Hanford Meteorological Station **1980-1984**

- Weather forecaster with an emphasis on wind forecasting at 60 m above the ground.
- Member of the emergency response program for the site running simulated wind flow conditions every month and doing research on regional wind flow patterns

Key Personnel

SELECTED PUBLICATIONS

1. Heimiller, D.; Haymes, S.; Schwartz, M.; Musial, W. (2007). Offshore Wind Resource Potential of the United States. Oceans 2007. 29 September - 4 October 2007, Vancouver, BC, Canada. Columbia, MD: Marine Technology Society (MTS) 8 pp.; NREL Report No. CP-581-43404. doi:10.1109/OCEANS.2007.4449210
2. Elliott, D.; Schwartz, M. (2006). Wind Resource Mapping for United States Offshore Areas. 1 p.; NREL Report No. PO-500-39971.
3. Elliott, D.; Schwartz, M. (2005). Development and Validation of High-Resolution State Wind Resource Maps for the United States. 14 pp.; NREL Report No. TP-500-38127.
4. Schwartz, M.; Elliott, D. (2005). Towards a Wind Energy Climatology at Advanced Turbine Hub-Heights: Preprint. 11 pp.; NREL Report No. CP-500-38109
5. Elliott, D.; Schwartz, M.; Scott, G. (2004). Wind Resource Base. Cleveland, C. J., editor-in-chief Encyclopedia of Energy. Elsevier Inc.; Vol. 6: pp. 465-479; NREL Report No. CH-500-33605
6. Brower, M.; Zack, J.W.; Bailey, B.; Schwartz, M.N.; Elliott, D.L. (2003) .Mesoscale Modeling as a Tool for Wind Resource Assessment and Mapping. ; NREL Report No. 35279
7. Schwartz, M.; Elliott, D. (2004). Validation of Updated State Wind Resource Maps for the United States: Preprint. 8 pp.; NREL Report No. CP-500-36200.
8. Milligan, M.; Schwartz, M.; Wan, Y. (2003). Statistical Wind Power Forecasting Models: Results for U.S. Wind Farms; Preprint . 17 pp.; NREL Report No. CP-500-33956.
9. Milligan, M. R.; Schwartz, M. N.; Wan, Y. H. (2003) Statistical Wind Power Forecasting for U.S. Wind Farms: Preprint. ; NREL Report No. CP-500-35087
10. Elliott, D.; Schwartz, M.; Scott, G.; Haymes, S.; Heimiller, D.; George, R. (2003). Wind Energy Resource Atlas of Armenia. 169 pp.; NREL Report No. TP-500-33544.

SYNERGISTIC ACTIVITIES:

Lead meteorological analyst for the wind resource assessment group at the NREL.

- Technical lead for preparing updated wind resource maps for U.S. states and selected foreign regions and countries. Closely work with Geographic Information System staff.
- Lead for validating state resource maps produced using mesoscale numerical modeling technique.
- Provide technical support to Wind Powering America Program and DOE Headquarter wind resource information requests
- Helped write and prepare wind resource atlases for USAID projects.
- Technical monitor for development of "Wind Resource Assessment Handbook"

Wind energy forecasting work:

- Lead NREL technical staff person to International Energy Agency Annex XI programs.
- Worked with AWS Scientific Inc. to provide background material on the needs of utilities for wind energy forecasting.
- Working with NOAA/Forecast Systems Laboratory on aspects of forecasting research.
- Provided support to of Electric Power Research Institute's (EPRI) Texas and California forecasting project.
- On the review panel EPRI/ California Independent Systems Operators wind forecasting project
- Developed guidelines for tall tower instrumentation and measurement

Technical leader for offshore wind resource assessment

- Leading effort to map, and validate wind resource for offshore areas of the United States. Will help design methodology to quantify offshore wind resource potential. Involved in investigating wind characteristics for marine boundary layer.

Key Personnel

Thomas L Stoffel

National Renewable Energy Laboratory

Principal Group Manager

EDUCATION AND TRAINING:

M.S., Atmospheric Science, 1976, University of Utah, Salt Lake City, UT
B.S., Aerospace Engineering, 1971, University of Colorado, Boulder, CO

PROFESSIONAL EXPERIENCE:

NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN, CO ***1978 – PRESENT***

Manager ***2001 - Present***

- *Responsible for 12 to 34 staff providing renewable energy resource data and information from measurements, modeling, and geographic information system analyses and products for biomass, geothermal, ocean, solar, and wind technologies.*
- *Work on projects ranging in scope from international, national, regional, state and local applications addressing the needs of policy makers, developers, designers, researchers, educators, and the consumer. Additional information is available from the Renewable Resource Data Center (http://www.nrel.gov/rredc), the Measurement & Instrumentation Data Center (http://www.nrel.gov/midc), and the Solar Radiation Research Laboratory web site (http://www.nrel.gov/solar_radiation).*

Research Scientist ***1978– 2001***

- *Provided technical leadership for the development and dissemination of renewable energy resource information.*
- *Developed the Solar Radiation Research Laboratory, providing an outdoor research capability for radiometer characterization, metrology lab, optics lab, data acquisition lab, and electronics lab support.*
- *Project leader for the Historically Black Colleges and Universities Solar Measurement Network providing long-term solar resource data in the southeast,*
- *Instrument Mentor for the ARM Program, providing benchmark radiation data for developing improved global circulation models.*

COOPERATIVE INSTITUTE FOR RESEARCH IN THE ENVIRONMENTAL SCIENCES, BOULDER, CO ***1976 – 1978***

Research Associate: Completed a published study of the urban-rural differences of solar radiation in the greater St. Louis, Missouri area using four years of irradiance measurements collected by the Environmental Protection Agency.

WRIGHT-PATTERSON AFB, OH ***1971 – 1974***

Aerospace Engineer: Provided computer simulations of gas turbine engine performance for developing aircraft systems. Specialized in the internal aerodynamics of gas turbines and their combustion systems. Used LOWTRAN to optimize afterburner designs for lower infrared signatures.

SELECTED PUBLICATIONS:

11. Heimiller, Donna; Renné, Dave; Stoffel, Tom. "Report to Congress on Renewable Energy Resource Assessment Information for the United States", 2007, https://apps3.eere.energy.gov/ba/pba/analysis_database/program_index_results.php?pid=2
12. Renné, Dave; George, Ray; Wilcox, Steve; Stoffel, Tom; Myers, Daryl; Heimiller, Donna. "Renewable Systems Interconnection Study", Chapter 9: Solar Resource Assessment, 2008, http://www1.eere.energy.gov/solar/solar_america/rsi.html

SYNERGISTIC ACTIVITIES:

- American Meteorological Society, member
- American Solar Energy Society, member
- American Association of State Climatologists, past member
- American Society of Heating and Air-Conditioning Engineers, past chair of Technical Committee 4.2, Weather Information

Key Personnel

Robert W. Thresher PhD, PE

Telephone: (303) 384-6922
E-mail: robert.thresher@nrel.gov

EDUCATION AND TRAINING:

Ph.D., Mechanical Engineering, Colorado State University, 1970
M.S., Mechanical Engineering, Michigan Technological University, 1967
B.S., Mechanical Engineering, Michigan Technological University, 1962

PROFESSIONAL EXPERIENCE:

Dr. Thresher has more than 40 years of research, development, engineering, and management experience in wind technology, plant engineering, and aerospace systems. As a professor at Oregon State University, he worked with DOE to develop early wind technologies. At NREL he has been a principal researcher developing early wind technology and an architect of the wind program at NREL and the creation of the National Wind Technology Center. He has been a strategist and spokesperson for the initiation of a national research program to develop offshore wind, wave, tidal and current energy technology. Dr. Thresher provides unparalleled expertise in research, development and commercialization of wind and ocean energy technologies. Dr. Thresher's key career accomplishments include:

- Developed NREL's wind program from $5 million to $30 million
- Received the H.M. Hubbard Award in recognition of outstanding leadership and initiative in science and technology management in 1990 by the Solar Energy Research Institute and the Midwest Research Institute
- Recognized as the 1997 Person of the Year by the American Wind Energy Association
- Inducted into the Academy of Mechanical Engineering and Engineering Mechanics, Michigan Technological University, "in recognition of significant contributions to the engineering profession," October 1996
- Awarded a Lifetime Achievement Award by the American Wind Energy Association in 2001
- Received the Pioneer Award from the World Renewable Energy Network at the World Renewable Energy Congress VIII, 2004

NATIONAL RENEWABLE ENERGY LABORATORY, GOLDEN CO	***1984 – PRESENT***
Wind Energy Research Fellow	*2008 - Present.*
Director, National Wind Technology Center	*1994 –April 2008*
Director, Utility Systems Division	*1993 - 1994*
Manager, Wind Research	*1984 - 1994*
Principal Scientist	*1984 - 1989*
OREGON STATE UNIVERSITY	***1970 – 1894***
Full Professor	

Key Personnel

SELECTED PUBLICATIONS

1. "Ecological impacts of wind energy development on bats: questions, research needs and hypotheses," Frontiers in Ecology and Environment 2007; 5(6): 315-324; with T. Kunz lead author, E. Arnett, W. Erickson, A. Hoar, G. Johnson, R. Larkin, D. Strickland, M. Tuttle.
2. "Impacts of Wind Energy Facilities on Wildlife and Wildlife Habitat," Technical Review 07-2, September 2007; The Wildlife Society.
3. "Advanced Wind Turbine Configurations." Pilot Issue of *Wind Energy,* May 1998, with D. Dodge.
4. "Structural Dynamic Behavior of Wind Turbines." Chapter 11 of *Wind Turbine Technologies*, American Society of Mechanical Engineers, 1994, with L.P. Merandy, T. G. Carne, and D. W. Lobitz.
5. "A Comparison of Predicted Wind Turbine Blade Loads to Test Measurements." ASME Journal of Solar Energy Engineering, 1988, with A. D. Wright.
6. "A Computer Analysis of Wind Turbine Blade Dynamic Loads." ASME Journal of Solar Energy Engineering, 1986. With A. D. Wright and E. L. Hershberg.
7. "Vibration Modes of Centrifugally-Stiffened Beams." ASME Journal of Applied Mechanics, Vol. 49, No1 pp197-202, March 1982 with A Wright, C. Smith, and J. Wang.
8. "Structural Dynamic Analysis of Wind Turbine Systems," ASME Journal of Solar Energy Engineering, May 1982
9. "Overview of Wind Energy Systems: Issues in Development and Application." ASME Journal of Solar Energy Engineering, pp.3-10, February 1981, with P.M. Moretti.
10. "Anchor-Last Deployment Simulation by Lumped Masses," Journal of Waterways, Harbors and Costal Engineering Division, pp 419-433, November 1975, with J.Nath.

SYNERGISTIC ACTIVITIES

- Alternate Member for the DOE to the Department of the Interior's Federal Advisory Committee for Wind Turbine Siting Guidelines. Starting February 2008.
- Member, ITI Energy Advisory Board, Scotland, UK providing high level advice to ITI Energy's Executive Director on strategies for developing new energy technologies.
- Member, The Science Advisory Committee for the Development of the "California Guidelines for Reducing Impacts to Birds and Bats from Wind Energy Development", California Energy Commission, 2006-7
- Member, EPRI Technical Advisory Team for the "Wave Power Feasibility Demonstration Project, 2003 – Ongoing
- Testimony before the Senate U.S. Senate Energy and Natural Resources Committee on the "Feasibility of Wind and Wave Development on the Outer Continental Shelf", April 19, 2005

Key Personnel

Dr. James H. VanZwieten Jr.

Research Professor
a101 North Beach Road
Dania Beach, FL 33004
(954) 924-7097
jvanzwi@fau.edu

Education and Training

2007 **Florida Atlantic University**
Ph.D., Ocean Engineering

2003 **Florida Atlantic University**
M.S., Ocean Engineering

2003 **Florida Atlantic University**
B.S., Ocean Engineering

Professional Experience

2008-2009 **Florida Atlantic University's Center for Ocean Energy Technology** Dania Beach, FL
Research Professor
My responsibilities at the Center for Ocean Energy Technology include supervising graduate students, assembling and testing ocean thermal and kinetic measuring systems, and ocean current turbine design, simulation, and optimization.

2007-2008 **Florida Atlantic University's Ocean Engineering Department** Dania Beach, FL
Research Engineer
My responsibilities as a research engineer in FAU's Ocean Engineering department included developing control systems for FAU's Rapidly Deployable Stable Platform (RDSP) and Small-To-Large Vessel At Sea Transfer (STLVAST) projects, conducting offshore experiments and measurements, and development and testing of a $1/10^{th}$ scale prototype of the RDSP.

2003-2007 **Florida Atlantic University's Center for Ocean Energy Technology** Dania Beach, FL
Research Assistant/Teaching Assistant
My responsibilities as a research assistant at FAU included developing curriculum for and teaching courses in offshore structures, computer simulation, and controls, developing a computer simulation and dynamic positioning control systems for twin screw vessels, and conducting offshore experiments.

2001-2003 **Florida Atlantic University's Center for Ocean Energy Technology** Dania Beach, FL
Graduate Research Assistant
My responsibilities as a research assistant included developing a computer simulation for an ocean current turbine, developing control systems for an ocean current turbine, and assisting on offshore measurements

Key Personnel

Publications

J. VanZwieten (2003) "Modeling and control of the C-Plane ocean current turbine" Masters Thesis, Florida Atlantic University

J. VanZwieten, F.R. Driscoll, A. Leonessa, and G. Deane (2006) "Design of a prototype ocean current turbine - Part I: mathematical modeling and dynamics simulation," Ocean Engineering 33 1485-1521

J. VanZwieten, F.R. Driscoll, A. Leonessa, and G. Deane (2006) "Design of a prototype ocean current turbine - Part II: flight control system," Ocean Engineering 33 1522-1551

Applicant: Lockheed Martin Company

Topic Area: Topic Area 3: Advanced Water Power Market Acceleration Projects/Analysis and Assessments

Sub-topic Area: 3C: OTEC Life Cycle Costs Analysis

Principal Investigator: Richard Pavlosky, Senior Staff Project Engineer in the Global Sustainment Group within Lockheed Martin Maritime Systems and Sensors

Title: OTEC Life Cycle Costs Analysis

Objectives:

1. Modify our current grid-connected OTEC design and cost estimates for application at multiple locations and OTEC sizes.
2. Extrapolate our grid connected OTEC cost estimate to grazing OTEC plants
3. Identify start up costs.
4. Identify likely evolution of future OTEC for lower cost and higher performance.
5. Define costs and schedule for required permitting and environmental compliance
6. Develop Life Cycle Cost estimates for the baseline OTEC system
7. Perform an economic analysis of the OTEC cost of electricity (COE) as well as generating Energy Supply Curves for OTEC plants of the future
8. Make the results of this work available to the public by publishing it on the Internet and by preparing and presenting technical papers on the results.

Description: We propose to develop and describe notional designs, performance and costs for both the nearshore and offshore OTEC baselines based heavily on recent OTEC work performed by our team. For the offshore OTEC, we plan to extend the ONR SBIR work recently completed by Makai Ocean Engineering on defining the performance and cost of a large offshore OTEC industry. We will integrate in the latest capital costs and operational understandings from the ongoing 100MW plant ship designs, extrapolate from these baselines, and will apply the Total Ownership Cost / Life Cycle Cost analysis to derive future O&M and life cycle cost. For each baseline, several scenarios will be evaluated to develop energy supply curves.

Potential Impact: The financial analysis resulting from this project will have the needed fidelity and high confidence level for decision-makers in Government and industry to assess the commercial viability of both nearshore OTEC cabled to local grids and grazing OTEC plants producing an energy carrier for use in the continental United States.

Major Participants: Lockheed Martin is the Prime Contractor for the OTEC Life Cycle Cost Analysis with teammates Makai Ocean Engineering, G. Noland & Associates, Inc., John Halkyard & Associates, Inc., Glosten Associates and Planning Solutions Inc.

School of Ocean and Earth Science and Technology
Hawai'i Natural Energy Institute

UNIVERSITY of HAWAI'I® MĀNOA

June 1, 2009

Mr. August Walker
Lockheed Martin MS2
9500 Godwin Dr.
Manassas, VA 20110

RE: Letter of Support for Lockheed-Martin Advanced Water Power Proposal under DE-FOA-0000069

Dear Mr. Walker,

The Hawaii National Marine Renewable Energy Center (NMREC) is led by the Hawaii Natural Energy Institute (HNEI) of the School of Ocean and Earth Science and Technology (SOEST) of the University of Hawaii (UH). The objectives of the NMREC are to facilitate demonstration of grid connected wave energy generation technology and to advance the state-of-the-art for Ocean Thermal Energy Conversion Technology. Issues associated with local and large scale environmental issues and resource assessments are of significant interest to the Center. Thus, the Hawaii Natural Energy Institute (HNEI), is pleased to support Lockheed-Martin's (LM)proposal to the U.S. Department of Energy for the Advanced Water Power funding opportunity DE-FOA 0000069 under Topic Area 3D: "Ocean Thermal Extractable Energy Visualization".

Under LM's proposal, faculty from SOEST propose to provide support in the area of Ocean Circulation Data Generation as detailed in the proposal.

Performance of the work will be contingent upon negotiation of a mutually acceptable agreement between UH and LM.

Sincerely,

Richard C Rocheleau

Richard Rocheleau
Director

1680 East-West Road, POST 109, Honolulu, Hawai'i 96822
Telephone: (808) 956-8890 Fax: (808) 956-2336

National Renewable Energy Laboratory
Innovation for Our Energy Future

May 29, 2009

August Walker
Lockheed Martin MS2
9500 Godwin Drive
Manassas, VA 20110

RE: Advanced Water Power – Program Announcement
Funding Opportunity Number: DE-FOA-0000069
Topic Area 3D: An assessment of global and domestic U.S. ocean thermal energy resources to determine maximum practicably extractable energy.

Dear Mr. Walker:

I am writing to confirm our intent to collaborate with Lockheed Martin Maritime Systems & Sensors on their proposal, entitled "Ocean Thermal Extractable Energy Visualization" submitted under Topic Area 3D: An assessment of global and domestic U.S. ocean thermal energy resources to determine maximum practicably extractable energy. Based on preliminary discussions, we are happy to provide support as outlined on the Field Work Proposal and estimate our total level of effort at $125K over a two year performance period. Of course, a more detailed cost estimate will be prepared with a successful award and with concurrence of our DOE sponsors.

NREL looks forward to working with colleagues on the Lockheed Martin team in this important area of research.

Sincerely Yours,

Fort Felker
Center Director
NREL's National Wind Technology Center

cc: Technology Transfer Office, NREL
George Scott
Tom Stoffel
OMS #10682

FLORIDA ATLANTIC UNIVERSITY
CENTER FOR OCEAN ENERGY TECHNOLOGY

June 1, 2009

August Walker
Lockheed Martin Marine Systems & Sensors
9500 Godwin Drive
Manassas, VA 20110

Dear Mr. Walker:

Florida Atlantic University is pleased to confirm its commitment as a participant with Lockheed Martin MS2 for Topic Area 3D application entitled "An assessment of global and domestic U.S. ocean thermal energy resources to determine maximum practicably extractable energy.

Sincerely,

Susan H. Skemp

Susan H. Skemp
Executive Director
Center for Ocean Energy Technology

777 Glades Road, Boca Raton, FL 33431
sskemp@fau.edu // 561-297-2339

DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT & TOURISM

LINDA LINGLE
GOVERNOR
THEODORE E. LIU
DIRECTOR
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DEPUTY DIRECTOR

No. 1 Capitol District Building, 250 South Hotel Street, 5th Floor, Honolulu, Hawaii 96813
Mailing Address: P.O. Box 2359, Honolulu, Hawaii 96804
Web site: www.hawaii.gov/dbedt

Telephone: (808) 586-2355
Fax: (808) 586-2377

June 1, 2009

Mr. Ted G. Johnson
Director, Alternative Energy Programs Development
Lockheed Martin
9500 Godwin Drive
M/S 400/046
Manassas, Virginia 20110

Dear Mr. Johnson:

I am writing to express support for the project proposed by Lockheed Martin in response to the U.S. Department of Energy's Funding Announcement DE-FOA-0000069 for Advanced Water Power. Your proposal addresses Topic 3D, Assessment of Maximum Practicably Extractable Energy from OTEC.

Surrounded by the Pacific Ocean, Hawaii is in a unique position to transform ocean energies into electricity. Our state's record of cutting-edge Ocean Thermal Energy Conversion research, some of it performed in partnership with Lockheed, and our critical need to reduce the use of imported fossil fuels makes this proposal an urgent one for Hawaii.

OTEC also has the potential to provide electricity or fuels for the rest of the United States, including its Pacific territories and military bases. Hawaii projects and successes can serve as a model for the rest of the U.S. and for island areas around the world.

Lockheed Martin, as the leading partner of an industry-academic-federal partnership, aims to develop a comprehensive GIS-based dataset and software tool and then use that tool to provide a meaningful assessment of maximum practicably extractable energy from the global and domestic U.S. ocean thermal resource. "Maximum practicably extractable energy" is defined as being sustainable and technically feasible, given today's state-of-the-art ocean structure technology and foreseeable future improvements.

Performing the research, development and demonstration necessary to bring OTEC to full commercial status is an important part of the Hawaii Clean Energy Initiative's bold, innovative, and comprehensive commitment to transform Hawaii's electricity and energy systems to be 70% powered by energy efficient and renewable energy technologies by 2030.

In October of 2008, Governor Lingle signed an Agreement with the Hawaiian Electric Companies to advance the implementation of renewable energy, increase energy efficiency, and improve grid operation and infrastructure. The deployment of OTEC plants was explicitly included in the Agreement. In addition, in November 2008 Governor Lingle facilitated an agreement between Lockheed Martin and the Industrial Technology Research Institute of Taiwan to explore the development of OTEC in Hawaii and in Taiwan.

Hawaii is an ideal location for ocean thermal energy conversion, with warm, tropical surface waters as well as cold, deep waters close to shore. OTEC promises to provide clean, renewable base load constant energy. I wish you success on this project.

Sincerely,

Theodore E. Liu

cc: Mital Gandhi, Lockheed Martin

OCEAN THERMAL EXTRACTABLE ENERGY VISUALIZATION

Advanced Water Power Projects Funding Opportunity Announcement Number DE-FOA-0000069

CFDA Number 81.087

Proposed under FOA Topic Area #3, Subtopic D: An assessment of global and domestic U.S. ocean thermal energy resources to determine maximum practicably extractable energy

Proposal Submitted by:

Lockheed Martin
Maritime Systems & Sensors
New Ventures
9500 Godwin Drive
Manassas, VA 20110-4157

Table of Contents

1 Project Objectives

The focus of this project is assessing the Maximum Practicably Extractable Energy from the Ocean Thermal resource. Maximum Practicably Extractable Energy (MPEE) is defined as being sustainable and technically feasible, given today's state-of-the-art ocean energy technology and foreseeable future improvements. At present, there is no clear way to assess this in a geospatial, time-varying way. Lockheed Martin MS2 (LM – MS2) and its team members, Florida Atlantic University's Center for Ocean Energy Technology (FAU – COET), University of Hawaii's Hawaii Natural Energy Institute (UH – HNEI) and the Hawaii Institute of Geophysics and Planetology (UH – HIGP) and, the National Renewable Energy Laboratory (NREL) aim to overcome this by developing a comprehensive Geospatial Information System (GIS) dataset and software tool, and then use the tool to provide a meaningful assessment of MPEE from the global and domestic U.S. ocean thermal resource.

The proposed Ocean Thermal Extractable Energy Visualization (OTEEV) project leverages existing NREL renewable energy GIS technologies and integrates extractable energy estimated from quality-controlled data and projected optimal achievable energy conversion rates. Data are synthesized from a broad range of existing in-situ measurements and ground-truthed numerical models with temporal and spatial resolutions selected to reflect the local resource. Energy production rates are calculated for regional areas based on conversion rates estimated for attainable future technology, local energy density of the resource, and sustainable resource extraction. Plant spacing and maximum production rates can then be estimated based on a default plant size and transmission mechanisms. All data is organized, displayed, and accessed using a multi-layered GIS with a user-friendly graphical user interface.

To achieve these goals, the partnership has set the following objectives:

1. Compile for input into the OTEEV energy conversion model the necessary and sufficient sets of quality data synthesized from a broad range of existing (historic) sources (measurement databases and numerical model data) that accurately represent (and provide the basis for) the global ocean thermal energy resource.
2. Establish parametric criteria for determining viability of ocean thermal energy extraction methods based on ocean thermal profile, bathymetry, proximity to power grids and resource energy density.
3. Develop parametric models to calculate the ocean thermal MPEE based on likely future technology performance, sustainable resource extraction, and resource energy density.
4. Extend NREL's existing GIS technologies to include a global ocean thermal component capable of displaying global and US domestic ocean thermal viable extraction mechanisms and MPEE information.
5. Apply the GIS tool to develop and deploy the information layers and data access methods needed to readily access and understand the global and U.S. domestic ocean thermal resource.
6. Publish results and disseminate novel insights into regionally available MPEE to policy-makers, the energy industry and the public to help accelerate market penetration and commercialization of ocean thermal energy extraction.

The primary effort focuses on providing a detailed analysis and assessment of energy extracted from the global and U.S. domestic oceans using Ocean Thermal Energy Conversion (OTEC), and a secondary effort is to utilize data collected to identify areas where the cold water resource is accessi-

ble to provide Cold Seawater Based Air Conditioning (CSBAC).

The following high-level requirements are established to ensure the project objectives are achieved:

1. Database development:
   a. All data will meet quality control (QC) standards defined by the team early in the work. The QC standards will be documented throughout the project.
   b. Direct observations will be used when possible.
   c. The database will be based on measurements that can capture the magnitude and phase of the seasonal cycle of the ocean thermal resource and can accurately represent the local resource.
2. Parametric models:
   a. Parametric models will be based on achievable future technology performance, and
   b. Parametric models must account for physical limitations of the ocean thermal resource.
3. GIS tool:
   a. The GIS tool will be user-friendly, publically accessible, and conform to community-based GIS standards.
   b. It will be flexible and readily able to incorporate new data and novel understanding of the resource limits.
   c. It will account for geographic variability of the resource.
   d. The GIS tool developed here will integrate with NREL's GIS tools in order to compare multiple resources.

2 Merit Review Criteria

2.1 Technical Merit and Innovation

2.1.1 Applicability to Industry Wide Use

Until recently, ocean thermal energy in general, and OTEC specifically, was not regarded as a significantly accessible renewable energy resource, nor considered an important alternative to fossil fuels. OTEC is only feasible with very large scale plants and therefore requires very large capital investments to be economically competitive. CSBAC also is viewed as capital intensive and requires significant infrastructure modifications. Because of high capital costs and a lack of detailed understanding of the available resource, ocean thermal energy extraction has been viewed as a solution for very limited sites, none of which are proposed to be tied into the mainland United States grid.

Today, the urgency for renewable energy development and concerns for the environment are high, and resources such as ocean thermal energy are again being seriously considered for commercial application. OTEC provides the potential for electricity cabled directly to local grids wherever a plant can be located within an economically feasible distance from shore. At further distances, OTEC platforms can manufacture energy carriers such as ammonia or hydrogen that can be shipped to shore for subsequent utilization. Future applications include building plants of sufficient size to host energy intensive manufacturing processes and the potential for synthetic fuel production. Shore access to cold seawater resources enables the benefit of sea water cooling to areas with significant air conditioning loads.

Industry wide OTEC and CSBAC deployment and development depends on demonstration of ocean thermal energy as a viable renewable energy resource. Therein lies the value of this Advanced Water Power subtopic – what is the potential ocean thermal energy resource? The Department of Energy (DOE) developed a global OTEC Thermal Resource Map (see Figure 1) in the 1970s depicting ocean areas with sufficient temperature differences between the surface and 1000 m depths to support OTEC processes. It offers no quantitative assessment of the resource capacity, does not address CSBAC, and does not address regions inside the 1,000 meter depth contour.

Even at the most conservative global estimate of 3 terawatts[1], the OTEC resource is large enough to be of commercial interest once the technology is shown to be commercially viable. The existing estimates are global in nature and provide no insights into regional or local resources. No tool exists today to allow regional or local estimates of ocean thermal extractable energy.

[1] Gerard C. Nihous, An Order-of-Magnitude Estimate of Ocean Thermal Energy Conversion Resources, Transactions of the ASME, pp 328-333. Vol. 127, December 2005.

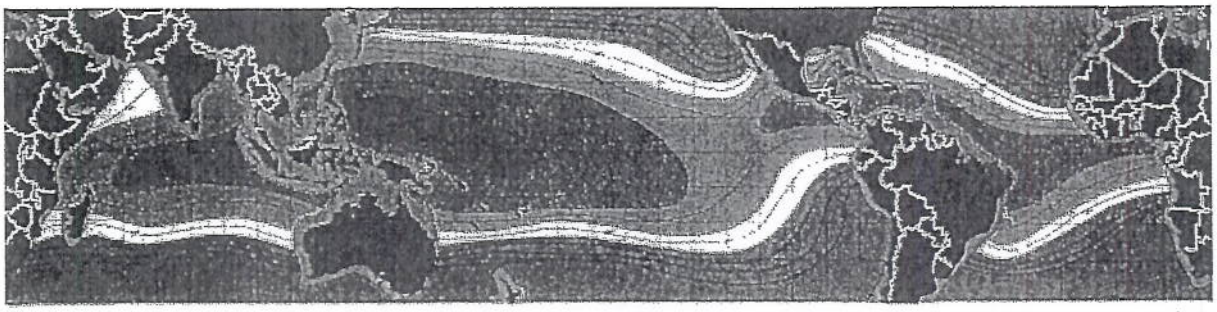

Figure 1 OTEC Resource, Circa 1978

A key to building support for ocean thermal energy extraction commercialization is the ability to provide estimates of ocean thermal resources at a regional or local level. For example, if a regional utility in Florida understood that OTEC plants could provide gigawatts of base load, renewable power directly cabled into high load areas, interest in the technology would dramatically increase, resulting in market penetration and commercialization. Municipal leaders would be better able to make utility decisions if they understood the potential capacity of CSBAC. Support for mature OTEC technology would rise and greater numbers of industry members would take notice and determine how they might take advantage of the new markets. The OTEEV project focuses on fulfilling this need for regional insight to facilitate commercialization and market penetration of the ocean thermal energy resource.

2.1.2 Research Topics Applicability

The research and development proposed herein directly addresses topic 3D: *An assessment of global and U.S. ocean thermal energy resources to determine maximum practicably extractable energy.* Each task included in the project plan is required in order to complete the development of the OTEEV tool. Additionally, the OTEEV input dataset and the plan to distribute the work products publically through NREL are applicable to other topics in this task area because they provide a comprehensive and readily available source of information to industry and other researchers.

One critical dataset required for this project is the estimation of the plant efficiency of an OTEC power plant. LM has an on-going OTEC Internal Research and Development (IRAD) program that has been active for the past three years. These efforts reestablish LM's pioneering OTEC work that was done in the late 1970s. The efficiency of the plant is particularly important to understanding and calculating the MPEE from the ocean thermal resource at specific locations. As part of this effort to determine the MPEE, LM provides our most up-to-date understanding of these efficiencies based on our study and refinement of the individual components of the OTEC plant such as heat exchangers, pumps, and others. These studies also are intended to estimate the potential for improvements and thus predict what the efficiencies will be in the future.

Additional research topics applicable to this effort are the ocean circulation rates and patterns including deepwater advection (upwelling and down-welling), and horizontal ocean currents. Estimates of ocean circulation will be made from data collected in the first step of this research effort and are used to assist in understanding the replenishment rates of deep, cold water and the surface warm water that are drawn into the plant. As a location becomes more populated with OTEC plants, the limiting factor for determining MPEE is the warm and cold-water replenishment rates, governed by these various geophysical properties. If the rate of energy extraction exceeds the replenishment rate, the efficiency of the heat exchangers will be reduced, thereby decreasing the OTEC plant efficiency. Understanding and modeling these phenomena are critical to determining limitations to the extractable energy at specific locations and hence directly applicable to the project.

Two products that result from this study, the OTEEV input dataset and the OTEEV tool, are directly applicable to meeting the needs of energy developers and policymakers because they characterize the energy available in specific locations. The proposed OTEEV tool includes effects of sea-

sonal variability so that a comprehensive understanding of the economics of energy production can be determined by matching seasonal supply with demand. The database is structured such that it can accommodate data as it becomes available and therefore applicable to meet future needs with updated data.

The OTEEV input dataset and tool are designed to be compatible with the existing architecture used for analogous databases for other sources of energy, such as NREL's studies of solar, geothermal, bio and biodiesel fuels. Structuring the database for energy produced by an OTEC facility and energy use avoidance through CSBAC similar to databases for other energy sources ensures that the ocean thermal energy resource can be compared to other renewable energy resources and that the database conforms to widely accepted resource assessment metrics and standards. Because the OTEEV input dataset, model and tool allow comparison between and among disparate energy sources, they are directly applicable to the needs of industry and policy makers in their development of plans to provide electric power at various locations.

In order to establish boundaries for this project, the OTEEV team has evaluated the scope of the modeling effort in the context of how comprehensive the model should be, given the time frame and resources of this effort. The output of the proposed OTEEV model is the MPEE at specific locations. The model takes into account the water intake and effluent of OTEC and CSBAC facilities, the replenishment rate of cold and warm water by circulation, advection, currents and other geophysical parameters. The spacing between multiple OTEC plants can be determined from this data based on the capacity of the individual OTEC plants and the available energy density of the location. Because the temperature difference can be reduced after prolonged operation of multiple, closely located plants, the extraction rate is an important parameter. This phenomenon has been observed in other studies[2,3]. The OTEEV team recognizes that massive ocean thermal energy extraction has the potential for changing global ocean circulation and affecting the rate of global climate change. However, existing ocean circulation models have not developed to the point of being validated for such predictions. The task of reconciling the various ocean circulation model results and developing or validating a model for predicting the impact of massive ocean thermal energy extraction exceeds the scope and timeframe of this solicitation. The OTEEV model is not intended to provide an estimate of the influence of multiple operating OTEC plants and CSBAC facilities on changes to the thermohaline circulation, nor does the approach attempt to calculate the effect of multiple plants and facilities on climate change or any other fundamental change to the global environment. While global climate change is outside the scope of this project, local environmental impacts are evaluated as necessary to assess extractable energy by focusing on sustainable thermal extraction.

The ability to disseminate the results of these studies is directly applicable to the success of this project. Therefore, we have included NREL on the team and assigned them the role of optimizing the availability of the OTEEV input dataset and tool to other users interested in developing ocean energy technologies, and to the general public. NREL also serves as a central point-of-contact to other groups funded by this solicitation, thereby making the oceanographic data available for studies directed toward various forms of ocean energy such as wave and current. The information from this study also supports the development of Projected Life Cycle Costs. As noted in Section 2.4 Information Dissemination, the OTEEV tool and supporting data will be made available from the NREL web site without charge.

[2] Alan F. Blumberg and George L. Mellor, "A Whole Basin Model of the Gulf of Mexico", Proceedings of 6th OTEC Conference, G.L. Dugger, Editor, Washington, D.C., June 1979.

[3] Martin, P. J., and Roberts, G. O., "An Estimate of the Impact of OTEC Operation on the Vertical Distribution of Heat in the Gulf of Mexico," *Proc. 4th Annual Conf. on OTEC*, pp. 26–34, 1977.

2.1.3 Comparison to Current State-of-the-Art

Little information exists today regarding MPEE from ocean thermal resources or the viability of ocean thermal energy extraction, and there are no estimates of the resource on a regional basis that use the most up-to-date methods and are available to the public in a convenient web-based form. The present study intends to remedy the lack of detailed information on this resource by using the latest modeling techniques and disseminating the results on a publicly-accessible GIS web site.

Existing OTEC resource maps provide temperature differences between warm surface water and cold deep water at a pre-defined depth (usually 1000 m). They do not address temperature differences in locations with shallower water depths than the default cold water depth and they do not include data on flow due to advection or currents. Further, the existing maps are static in nature and do not allow for querying or data extraction. Existing OTEC extractable energy models consider global thermohaline circulation to provide extractable energy estimates at a global level with no insight into regional resources or plant site feasibility. No comprehensive CSBAC resource maps exist. The modeling approach being undertaken as part of this project progresses beyond what has been done to date by using regional advection rates, adding the component of heat flux supplied by ocean currents and considering variable cold water source depths. The primary output of the proposed OTEEV project is the MPEE at each grid point for a unit area of ocean. By using an energy conversion model (see Section 2.2.2.2 Energy Conversion Model Development for a description) that can be optimized for varying cold water depths and available ocean thermal energy, calculation of extractable energy estimates are made for all regions including those with less than 1000m water depths. These energy estimates go well beyond the simple temperature-difference estimates by including detailed knowledge of the ocean circulation. Inclusion of the circulation is vital when computing a sustainable energy resource value.

Web-based GIS databases of renewable resource estimates have proven to be very useful tools for developers of wind, solar and other technologies, but no such databases exist for ocean thermal energy resources. The NREL GIS team analyzes wind, solar, biomass, geothermal and other energy resources and adds the data to its online maps and databases (www.nrel.gov/gis). NREL's most comprehensive GIS database is the U.S. Atlas of Renewable Resources, which can be easily extended to include the OTEC and CSBAC resource assessments produced in this project. Once the OTEC and CSBAC data are integrated into the atlas, users are able to query the database, generate maps and compare the OTEC and CSBAC energy resource to the resources from other renewable energy sources. Ancillary data such as bathymetry and average ocean currents can also be added to the atlas to provide additional information for users.

NREL also maintains and distributes various analysis tools and renewable energy databases. Hosting the OTEEV tool at NREL allows the OTEC and CSBAC resource to be included in future versions of these tools and databases. For example, NREL creates Geospatial Toolkits, standalone map-based software applications for specific countries or regions. These toolkits are used for decision-making and policy analysis in addition to planning for future renewable energy projects, and could be modified to include the ocean thermal resource.

This project also takes an additional step to quantify not only the raw resource but the sustainable, extractable energy from that resource. This novel approach will provide industry and policymakers valuable insight into the commercialization and exploitation of this vast, currently unharnessed resource.

2.2 Technical Approach

Ocean thermal energy is the potential energy stored in the ocean thermal stratification. The ocean thermal stratification is governed by complex fluid dynamics and thermodynamics. There are two fundamental components to the ocean thermal resource, the warm surface water and the deep cold water. Ocean thermal stratification is produced by surface solar radiation that warms the upper layer, and cold deep water that is formed at high latitudes and circulates throughout the globe. The ocean thermal resource can be harnessed to produce energy as well as to provide equivalent

energy reduction. The known technologies for extracting ocean thermal energy are 1) Ocean Thermal Energy Conversion (OTEC), 2) Cold Seawater Based Air Conditioning (CSBAC) 3) Arctic Ocean-Air Energy Conversion (AOAEC)

OTEC utilizes a thermodynamic cycle to convert ocean temperature gradients between the warm and cold water sources to usable energy. OTEC thermal resources are expected to be limited by heat flux into the regions of interest. As a result, a regional assessment of MPEE is provided for this technology.

CSBAC utilizes the cold deep water of the ocean to act as a chiller in conventional air conditioning systems, replacing energy-intensive electricity-based chillers and yielding energy savings. CSBAC is limited to regions within a few miles of shore and is practically inexhaustible. Locations where exploitation of this resource is feasible are identified.

AOAEC is similar in concept to OTEC, except that the cold sink is arctic air and the heat source is the Arctic Ocean. AOAEC is a new concept that merits further study. The OTEEV model and tool is designed to easily add AOAEC energy estimates. However, generation of those estimates is beyond the scope and funding of this project.

The principle focus of the OTEEV project is the development of a GIS-based tool to provide summary estimates of the potential for MPEE from the ocean thermal resource focusing on global and U.S. domestic OTEC with identification of regions with accessible CSBAC resources.

2.2.1 Methodology

The objective of our project is to develop a model that utilizes a geospatial oceanographic database to provide the MPEE from thermal resources in any specified world-wide region defined by GIS coordinates to facilitate market penetration of ocean thermal energy extraction. To meet that objective, our methodology consists of assembling the right expertise to define and execute the proper technical approach with well established quality controls in place. To that end we have assembled a well rounded team to properly address all aspect of this project.

LM is home to OTEC New Ventures and brings experience from its internally funded three year research and development program to incorporate modern technology into OTEC designs indispensable to providing program leadership to this project as well as development of the OTEEV model. FAU is the home of Florida's Center for Ocean Energy Technology and the Institute for Ocean and Systems Engineering and brings extensive ocean engineering and physical oceanography knowledge key to providing technical leadership and guidance to this project as well as compiling the necessary data inputs to drive the OTEEV model. UH is home to the Hawaii Natural Energy Institute and Hawaii Institute of Geophysics and Planetology and brings particular expertise of ocean circulation, as well as a background on ocean energy studies critical to providing required insight into the impacts of advection and currents on ocean thermal energy extraction sustainability. NREL is home to the US Atlas of Renewable Resources and brings experience in developing web hosted GIS tools including estimates for wind, solar, biomass and geothermal resources, essential to facilitating the definition and integration of the OTEEV model output into a readily accessible GIS-based tool compatible with existing renewable energy resources estimations. NREL's extensive experience in renewable energy technology makes them uniquely qualified to provide independent validation and verification of the data, methods, techniques and formats used in the OTEEV project.

Our technical approach begins with the collection of the oceanographic and bathymetric data required for developing the comprehensive OTEEV input dataset. This effort focuses on geophysical data and its relative seasonal variability. As shown in Figure 2, when gaps exist for data that is required to complete the OTEEV input dataset, either spatially or temporally, estimates are obtained from appropriate ocean models. FAU leads this effort. Additional key components of the oceanographic processes important for modeling extractable energy include the advection of deep cold water and the deep water global circulation. UH leads the team in this area by providing technical oversight and understanding in the integration of these physical processes into the OTEEV model. (The specific datasets and the process by which they are collected are described in Section 2.2.2.1 Resource Data Generation.)

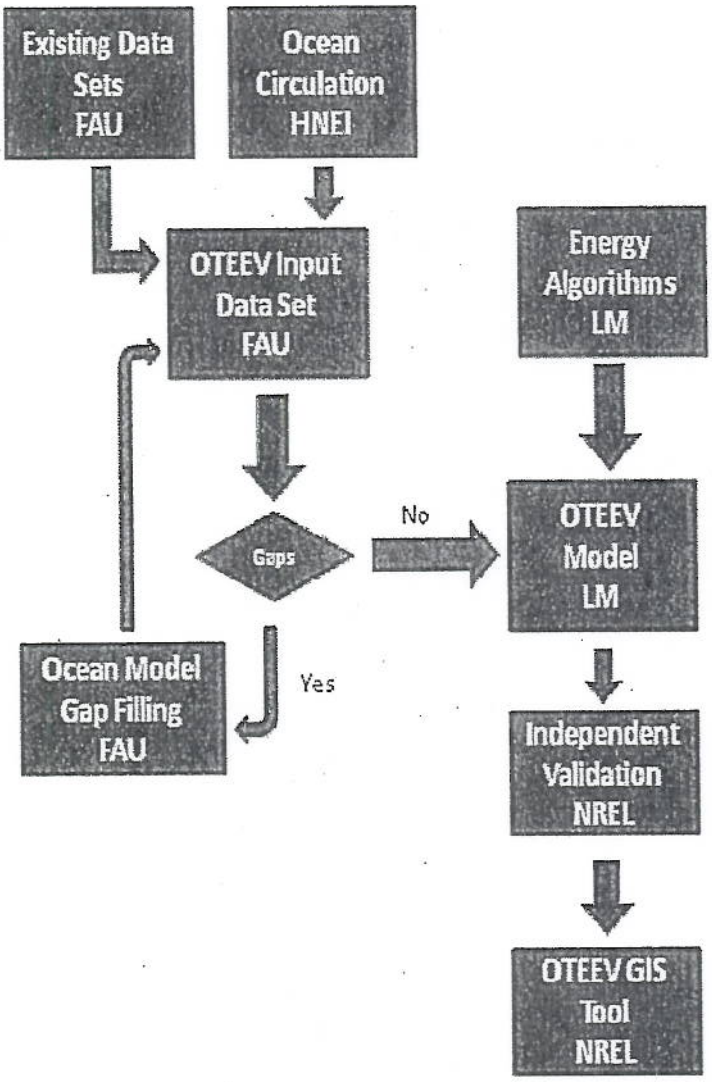

Figure 2 OTEEV Technical Approach

LM develops rules and criteria to apply to the OTEEV input dataset. Using critical parameters such as site location, proximity to electric grids, system design, advection, and sustainable extraction rates for ocean thermal energy plants, among others, the MPEE is calculated. (For detailed discussion see Section 2.2.2.2 Energy Conversion Model Development.)

The National Renewable Energy Laboratory provides leadership for the integration of the resource data and modeling efforts into a geospatial database for a range of offshore renewable energy resource types. This database can be used to produce and display resource maps of MPEE, temperature differences, water depth, and extraction and transmission mechanisms, for specific GIS coordinates. NREL integrates the ocean thermal energy resource values into its existing renewable resource GIS database so that users have a consistent interface and are able to easily compare various renewable resources.

A key component of our methodology is ensuring the quality of the data contained in the database and the accuracy of the algorithms that are applied. Both are critical to the usefulness of the final product. At the start of the project, requirements are established between all partners through an interface working group. The focus of the working group is to define a set of comprehensive requirements related to data collection, data formatting, gap filling, model interfaces (inputs and outputs), and GIS interfaces. Data/interface prototyping is employed during the data collection period to provide early integration activities focused on identifying and addressing interface issues. During the project performance, NREL is involved in every activity throughout the project as an independent reviewer to validate and verify the methodology, data quality, modeling techniques and GIS formatting to ensure a high quality product and conformity to widely accepted resource assessment metrics and standards.

2.2.2 Project Tasks

2.2.2.1 Resource Data Generation

Data is the foundation of this proposal and provides baseline input into the OTEEV model. Thus, to provide a real estimate of the MPEE for OTEC and identify regions where CSBAC is practical, high quality data (both spatial and temporal) are needed. This effort focuses on collecting existing/historic quality-controlled datasets. OTEC systems are envisioned to harness ocean thermal energy in the upper levels of the ocean and thus,

the OTEEV models require data measured from the surface to about 1500 meters that include:

1. ocean water temperature at the surface and throughout the water column to estimate resource potential, technology applicability (floating, shore, or subsurface), overall energy production, thickness of the mixed layer, location of the thermocline, etc;
2. ocean circulation information, including: surface currents, subsurface currents, advection, gyres, eddies, and other complex phenomena (magnitude, depth, direction, transport, etc);

In addition, ancillary data are needed to support calculations and technology specification such as:

1. global bathymetry to characterize seafloor topography leading to regionally-specific technology selection; and
2. deep water circulation (which is of particular importance to ensure an adequate cold water supply is maintained and sustainable).

The first step in database generation is developing data requirements. Because the ocean is a complex dynamic system characterized by very different scales of variability in physical parameters, data sampling requirements such as spatial and temporal resolution must reflect this. For example, mid-ocean basin water properties are much less variable than near-shore areas with significant tidal input. Other areas may have unique oceanographic properties, such as offshore Florida, where the Gulf Stream pumps warm Caribbean water over cold bottom water, yielding temperature differences of more than 20 degrees C in 200m. Interannual variability, such as that associated with El-Nino/Southern Oscillation (ENSO) events can have significant impact on OTEC operation, both by modifying current profiles, and by changing the availability (and temperature) of warm surface water and perhaps even deeper waters. Near shore, such events may result in significant advection anomalies that would, in turn, impact annual OTEC production in an affected region. Regions with high current, temperature variation, and significant current-driven temperature anomalies will be identified simultaneously with expected strength, frequency, and duration of the anomalies. Hence, as part of the data sampling methodology, the world ocean will be divided into geographic areas, and sampling requirements specified accordingly. Grid spacing for data collection is regionally specific with higher horizontal and/or vertical grid resolution in areas where higher physical gradients persist, such as coastal boundaries. Grid densities are coarser in areas of expected low physical gradients, such as in the open ocean. Global numerical ocean models are computationally intensive, and to minimize computational overhead while maximizing accuracy, these models include variable grid densities based on parametric (physical) gradients. Significant work has been invested in determining appropriate geographic grid densities, and these existing works are leveraged for this work. Naturally, all model-generated data are specified in the appropriate densities. Data is averaged to reflect the time constants appropriate for OTEC plants. In parallel, data requirements are chosen to reflect the needs of the energy production calculations. The goal is to develop a necessary and sufficient set of data requirements that yield an adequate dataset needed to determine the MPEE.

The second step in generating the database is gathering data from existing sources – no new ocean measurements or numerical simulations will be conducted with the requested funding. The proposed effort uses existing data produced from direct measurements and validated through quality control procedures. Prior ocean thermal resource assessments are limited due to data availability. Since these assessments were done, new local and remote measuring systems have been developed and deployed, and as a result new ocean observations are now available. These have greatly increased coverage of *in situ* and remotely sensed measurements. In parallel, the value of these new datasets has been recognized, and several centralized and publicly accessible databases have been established and populated with a wide range of new oceanographic data. Bathymetry, ocean currents, and ocean temperature are well represented in these. Some of the data sources that will be accessed include: NOAA's National Oceanographic Database, World Data Center databases, the National Geophysical Data Center, and Distributed Oceanographic Data Systems.

Even after combining new and old resources, existing data are still likely to be insufficient to provide a complete dataset needed to confidently assess the global and U.S. domestic ocean thermal resource. Thus, when direct measurements are not available or are insufficient, data gaps are filled

with numerical model output. Several different global ocean models are available for this study, including the data-assimilating ECCO-2 reanalysis, the SODA (Simple Ocean Data Assimilation) model, and the HYCOM (HYbrid Coordinate Ocean Model). These models are state-of-the-art systems and provide long-term estimates of ocean circulation (up to 50 years in the case of SODA) and up to very high resolution (1/12-degree for HYCOM). These models are selected because all runs incorporate data assimilation from a combination of available satellite surface measurements and *in situ* data, are publically available, and are widely used in the ocean research community. This provides a high level of confidence in the results from these models.

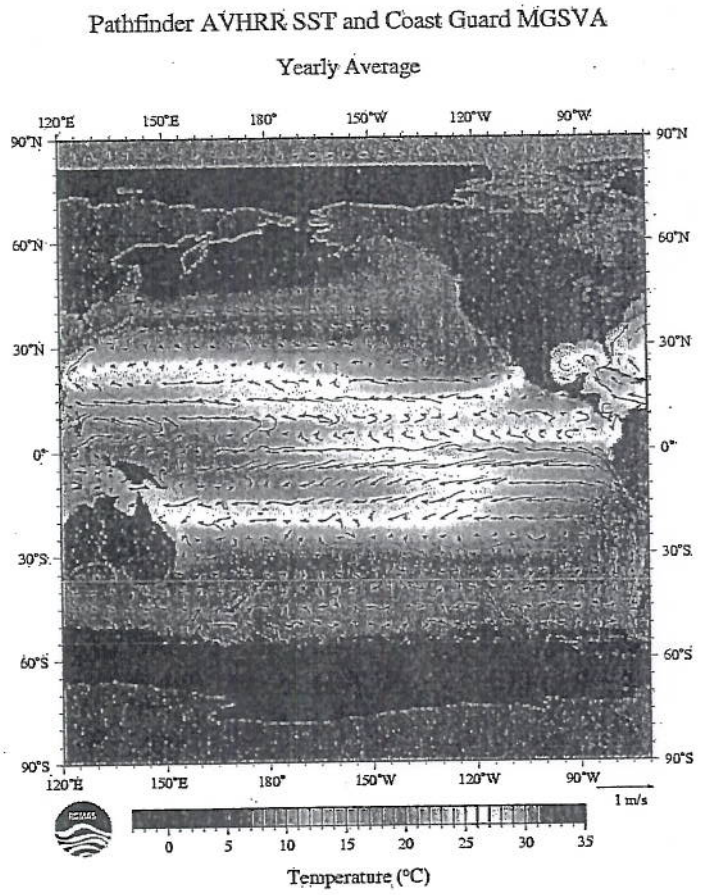

Figure 3 Example Ocean Circulation Database Visualization

The third step is to take the datasets from multiple (ideally redundant) sources and perform a final quality check to ensure that all data incorporated meet minimum data standards as developed in this overall effort, as well as those specified externally. The final step is to synthesize the data into one database and format the data based on the interface protocols and structure for the GIS and OTEEV model and import the data into the OTEEV input dataset.

2.2.2.2 Energy Conversion Model Development

There are two factors that impact MPEE for OTEC: plant efficiency and sustainable net heat flux available from the environment.

Plant Efficiency: OTEC plant efficiency is a complex function of the cold-water temperature (T_c), warm water temperature (T_h), flow rates and plant design

For the purposes of estimating MPEE, it is sufficient to reduce plant performance to an overall conversion efficiency matrix with T_c as one axis and T_h as the other. The overall efficiencies include both Carnot efficiencies and plant component efficiencies. The matrix is populated with data based on the best available designs. The matrix and other related data parameters are configurable. These data are available for future maintenance and upgrades as more efficient technologies are identified.

Achieved OTEC plant Carnot efficiency depends on component efficiencies (turbines, generators, pumps, heat exchangers etc.) and parasitic losses (sea water pumps, condensate pumps, hotel loads, etc.). The OTEEV team has developed OTEC designs over the last three years, together with models that predict performance. Some of these models evolved from work begun 25 or 30 years ago. OTEC models are used to develop the default tables. These data are incorporated into the overall plant efficiency matrix.

T_c and T_h can be extracted from the OTEEV input dataset at the nominal intake and exhaust

locations / types. The intake depths and exhaust locations are selected to be optimal within ranges that are controlled through configuration files.

Sustainable Heat Flux: There are two components to sustainable energy resources. The first is the global sustainability. The second is regional sustainability.

Sustainable, global ocean thermal resources have been estimated in a number of different ways, including total solar irradiation, global rain fall and thermohaline capacity. The most conservative estimates assume that the limiting resource is the thermohaline circulation which provides replenishment of cold water as it is removed by OTEC plants. This resource has been estimated at 15±2 million cubic meters per second. Under this proposed project, literature searches are employed to select a validated, representative value.

There is uncertainty about the fraction of the ocean thermal resource that can be safely consumed for energy extraction. The available global circulation models are not in good agreement nor have they been widely used to address OTEC-like perturbations. Without diminishing the importance of reconciling these models and evaluating the effects of ocean thermal resource extraction on global circulation, that effort is beyond the scope of this proposal. Rather, the fraction of the thermohaline heat flux used is an input parameter, allowing adaptation to future research results.

The natural way to quantify regional, sustainable resources is in terms of power density per unit area (megawatts/square kilometer). Viable device spacing is a derived output that depends on the OTEC plant size or capacity. OTEC plant size is governed by a combination of economic and technological considerations. Plant size is defaulted to 100 MW net power to produce plant spacing.

Regional, sustainable resources depend on the net heat flux into the region near the T_c and T_h intakes and discharges. OTEC becomes unsustainable once temperature differences fall below critical values. With current heat exchanger technology the minimum sustainable temperature difference is around 18 degrees C.

Depending on regional conditions, sustainable energy extraction differs significantly from averages, particularly in regions of persistent upwelling or down-welling. Thus, the OTEEV model estimates total heat flux into and out of the region of interest. Sensible heat flux, advection, temperature profiles and currents are used in this calculation. Thermal sources and sinks introduced by the plants are also included.

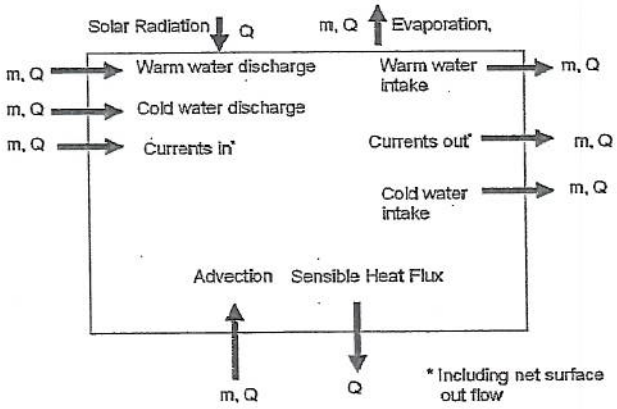

Figure 4 Ocean Thermal Energy Heat Balance

Figure 4 illustrates the various parameters that the OTEEV model considers in establishing the ocean thermal energy balance for OTEC. Since MPEE is desired, equilibrium heat transfer is used.

Models have shown[4] that if OTEC plants are placed too closely together they modify the ocean's thermal gradients and that eventually the cold water resource is degraded to the point that the plant becomes unsustainable. The model in question is two dimensional, does not include current effects, and assumes nominal (4 meters/year) up-welling. The existing modeling techniques must be enhanced to reflect these factors. Simplified calculations show that the upwelling rates required for maintaining the regional cold water supplies are very low and thus difficult to measure directly. As a result, proxies for the advection rates (for example upwelling derived from surface wind stress) are investigated. When the upwelling rates are adequate, the warm water is expected to be limiting for OTEC.

The results of the above models and analysis become inputs to the GIS system. The proposed OTEEV model is run at the temporal and spatial resolution of the underlying datasets and then the

[4] Gerard C. Nihous, A Preliminary Assessment of Ocean Thermal Energy Conversion Resources, Transactions of the ASME, pp 10-17 Vol. 129, March 2007.

results are use to produce seasonal and annual MPEE estimates.

The above discussion has focused on OTEC. CSBAC will also be evaluated, but the evaluation will be limited to identification of coastal regions where the resource is accessible (distance to resource and bathymetry make it practical to extract). This is due to the fact that regional use of cold ocean water for air conditioning will not tend to foul its own intakes due to surface currents, tides, etc. In addition, it appears to be unlikely that CSBAC needs will ever exceed the available capacity due to the limited regions (within a few miles of shore) where it is practical.

2.2.2.3 Incorporate Results into GIS Database

The overall objective of this task is to incorporate ocean thermal energy resource information along with consistent and reliable estimates of baseline, practical, recoverable and producible electrical energy in a public GIS database, consistent in format with other renewable energy data at the NREL. The ocean thermal energy resource information generated under the proposed OTEEV project is added to NREL's existing GIS databases of renewable energy resources, either as a new layer in an existing database or as a separate database. At the end of the period, NREL will host the database on its web servers. The required formats and mechanisms for updating the database are well documented as part of this project, so that updates can be easily implemented as more data and funding are made available.

At each spatial grid point, the following outputs from the OTEEV model are provided to the OTEEV tool:

1. Location (latitude/longitude)
2. OTEC viability (direct connect and offshore)
3. CSBAC viability
4. Average MW per unit area
    a. Annually
    b. Seasonally

Additional information, such as bathymetry, temperature differences, circulation rates and other quantities used to compute the extractable energy may also be supplied to NREL.

These quantities and other relevant information are added to the GIS database. Values of extractable energy are dependent on certain assumptions about plant efficiency. NREL is documenting these assumptions and providing confidence limits for extractable energy as an adjunct to the GIS database.

NREL's geospatial display capability includes graphical and/or tabular output tools for displaying the OTEEV model outputs listed above in the OTEEV tool.

2.2.2.4 Independent Validation and Verification

NREL evaluates, validates and verifies the input data for the OTEEV model, the methodology for computing the resource, and the final output products that are included in the geospatial ocean thermal energy resource database. In preparation for the validation of the input data, Lockheed Martin and its partners make available to NREL all input data that may be used in the development of the algorithms and in the resource modeling. NREL evaluates the data for quality issues such as length of period of record, data completeness, bad data periods, etc. If individual sites are selected, a data quality grade is assigned to each site. This data quality grade is included in the GIS database.

Lockheed Martin also provides NREL with a detailed description of the methodology used to compute the ocean thermal extractable energy from the input data, including details of all modeling software, examples of where this software has previously been used to compute ocean thermal resources, descriptions of new techniques or methods that are used in this study, etc. NREL evaluates and approves the methodology, and includes a description as an adjunct to the GIS database.

After the ocean thermal extractable energy data have been integrated into NREL's existing offshore renewable resource GIS, NREL conducts an internal review of the system to be certain that all project requirements have been met. NREL also seeks input from all project partners and from outside users to evaluate the usefulness of the system. Based on discussions with the project partners, changes and refinements to the system may be made before the final publication of the OTEEV tool.

2.2.3 Success Criteria & Risk Mitigation

Success in this project is defined as completing the development of three specific products, OTEEV input data, OTEEV model, and OTEEV tool, in accordance with their technical requirements and making these products available to the general public.

The first product that results from this project is the OTEEV input data. Key to the validity of this product is the accuracy and quality of the datasets that it contains.

One significant risk to the quality of the OTEEV input dataset is the potential for incompatibility between and among the multiple individual input datasets that must be gathered from previous studies. These studies were conducted by different researchers at different times and these potential differences must be accommodated in the OTEEV input dataset. Additionally, the data in the OTEEV input dataset must also be compatible with the OTEEV model inputs and outputs, and the OTEEV tool. To address this challenge, focus is placed on early definition of the interfaces and data format requirements of the various components. Well established, clearly defined interface requirements are established and agreed by all team members at the onset of the project. Data format prototyping and integration activities are undertaken early in the project to identify and address any compatibility issues.

The second product that results from this project is the OTEEV model. Success for this product is realized by its ability to accurately estimate the MPEE from ocean thermal resources. Several factors influence the model's ability to achieve accurate extractable energy estimation. These include the quality of input data, accuracy of energy conversion metrics, and energy conversion model fidelity. This accuracy is achieved by applying a comprehensive approach to model the energy producing system and its interaction with the ocean environment. Accuracy of the energy conversion metrics used in the calculation of the extractable energy estimate is driven by careful review of the currently available studies, and analysis, as well as through the independent validation and verification activity. Care is taken to use appropriate values based on state-of-the-art technology and knowledge as well as considering likely trends.

The quality of the raw data collected and incorporated into the energy conversion model has significant impact on the accuracy of the model results. To ensure high quality input data, quality checked data from credible sources and comparison of redundant data from multiple sources are used to build the input dataset. Gap filling of the input dataset is accomplished using verified ocean models. For geographical areas with sparsely collected data, the grid size selected for the input dataset is limited by the fidelity of the available ocean models. Care is taken to select grid sizes appropriate for the collected data and model fidelity to ensure that gap filling does not introduce unacceptable quality degradation.

The third product that results from this project is the OTEEV tool. This GIS-based system provides users with the final output of MPEE in a user friendly format. Success criteria for this product include the user friendliness of the product, the product's compatibility with analogous systems for other energy systems, and the ease with which the system can be enhanced and upgraded in the future. This success is achieved by building the architecture of the system such that it is compatible and consistent with other systems previously constructed by NREL.

2.3 Qualifications and Resources

2.3.1 Team Member Credentials

All of the institutions involved in this proposal have strong, demonstrated track histories in ocean and ocean energy research and development and all have demonstrated the ability to form successful collaborative partnerships. These are recognized as major technology providers and institutions of higher learning, with major research areas closely aligned with enabling open-ocean energy exploration. They have also shown a strong ability to develop innovative technologies from concept to commercialization and understand the realities of harnessing the ocean thermal resource.

Florida Atlantic University – FAU is classified as a High Research Activity institution by the Carnegie Foundation and is a national

leader in Ocean Engineering and Ocean Research. It is the home of Florida's Center for Ocean Energy Technology (COET), a $14M state funded research institute focused on establishing the appropriate framework, infrastructure, expertise, workforce, policy, and knowledge base, and carrying out fundamental research in areas of significant impact to the nascent ocean power industry. The COET was founded through a competitive grant from the Florida State University System's Center of Excellence Program to investigate ocean-based solutions to Florida's energy crisis. More recently, the Florida State Legislature established the Florida Energy Systems Consortium, of which Florida Atlantic University is a founding member with Florida State University, University of Central Florida, University of Florida (a land-grant university), and University of South Florida, and committed an additional allocation to COET for pursuit of research and development in ocean energy. Two FAU units are especially relevant to this proposal: The ***Institute for Ocean and Systems Engineering*** based in Dania Beach, Florida, where it houses the nation's largest and oldest ocean engineering program, and ***Harbor Branch Oceanographic Institute*** in Fort Pierce, Florida, which has over 40 years being leaders in ocean-related innovation, exploration, research, education, and conservation. The FAU family brings a broad range of technical and scientific expertise in all areas of the ocean and they have a strong track record of delivering results. Dr. Frederick R. Driscoll is the Technical Director for the COET and he is leading the FAU team. With his background and education in both engineering and physical oceanography, he has led the ocean energy efforts at FAU over the last 10 years, including ocean resource assessment, technology development, and prototype testing. Dr. Howard P. Hanson, the Scientific Director of the COET, works alongside Dr. Driscoll. Dr. Hanson has three decades of professional experience with, among other things, climatological data assembly and analysis in a variety of areas using disparate datasets from marine stratus and stratocumulus clouds to coastal cyclogenesis to seasonality of Great Lakes ice as reported by on-shore volunteers. Dr. James VanZwieten has been working in the area of ocean energy technology and resource assessment for over 5 years and has extensive experience with field measurements and data reduction. Ms. Anna Leland is completing her Masters Degree in the fall of 2009 and her thesis is focused on the assessment of the ocean thermal resource along the Florida Coast.

National Renewable Energy Laboratory – NREL is the nation's primary laboratory for renewable energy and energy efficiency research and development. NREL is owned by the Department of Energy and located in Golden, CO. Over its 32-year history, it has established a preeminent reputation in all renewable energy technologies, including OTEC. NREL's expertise includes technology research and development, resource assessment, GIS development, and dissemination of renewable energy information.

NREL has extensive experience in establishing and maintaining comprehensive global renewable energy resource databases. NREL receives data from a multitude of sources (including solar, wind, geothermal and biomass), organizes the databases for quick data accessibility on a national basis, and formats the data in a way that facilitates assessments of the renewable resource by a wide variety of users. The extent of the renewable resource databases at NREL are unmatched by any comparable organization. NREL also has far-reaching experience in validating renewable energy resource assessments using specialists in meteorology, GIS mapping scientists, and NREL's global databases. NREL's validations add accuracy, consistency, and confidence to the final renewable resource project, which can help break down barriers to renewable energy deployment.

NREL has been involved in OTEC for 30 years. Since 1979, NREL (then the Solar Energy Research Institute, SERI) has led the nation's OTEC research efforts.

Scientists and engineers at NREL have made many significant contributions to the design and operation of OTEC systems, including advancements in intake components and the design of evaporators with efficiencies as high as 97 percent.

NREL's resource assessment scientists have many years of experience in measuring, evaluating and analyzing all types of resource data, including wind, solar, biomass and geothermal. NREL's wind and solar maps of the US and various countries are recognized as the best available assessment of these resources. NREL's capabilities in

handling large datasets, quality control of all kinds of data, and dissemination of results will be directly transferable to the OTEC resource.

NREL's GIS team uses state-of-the-art geographic information system tools to organize, display, and analyze geospatial data important to solar, wind, biomass, hydrogen and geothermal technologies. The team manipulates, analyzes and compares the datasets to extract information for optimized technology deployment.

The GIS team also maintains a web site, where users can view a variety of interactive maps and download various datasets from an ftp site. Users can access some of NREL's solar and wind resource data as well as view and use the internet map server GIS capabilities through their web site at http://www.nrel.gov/gis.

The capabilities of GIS are greatly enhanced by NREL's team of experts who can perform the manipulation and analysis to link topographic, demographic, utility, facility, resource, environmental, land use, and other data for a variety of uses, including energy planning and forecasting, policy formulation, and project development assistance.

University of Hawaii – The UH contribution to this effort involves different units within the School of Ocean and Earth Science and Technology (SOEST), including the Hawaii Natural Energy Institute (HNEI), the Hawaii Institute of Geophysics and Planetology (HIGP) and the International Pacific Research Center (IPRC). HNEI will provide co-ordination and oversight for the UH group. Dr. James Potemra will provide technical expertise and analysis on general ocean circulation and ocean data acquisition and interpretation. Dr. Potemra's home institute within UH, HIGP, is a multi-disciplinary institute engaging in advanced research, teaching, and service in cutting-edge oceanographic, atmospheric, geophysical, geological, and planetary sciences. HIGP is home to over 130 faculty, staff, postdoctoral researchers, and graduate students with access to state-of-the-art laboratories and instrumentation. HIGP expertise spans the globe from pole to pole, from the depths of the seas to the tops of volcanoes and extends to the Moon, Mars, and beyond. Dr. Potemra is also affiliated with the IPRC whose mission is to provide an international, state-of-the art research environment to improve understanding of the nature and predictability of climate variability in the Asia-Pacific sector, including regional aspects of global environmental change. Within the IPRC, Dr. Potemra manages a climate data center (APDRC) which distributes over 100 different datasets via a variety of web-based servers to the research and general-user community.

Lockheed Martin – Headquartered in Bethesda, MD, Lockheed Martin is a global security company that employs about 146,000 people worldwide and is principally engaged in the research, design, development, manufacture, integration and sustainment of advanced technology systems, products and services. The OTEEV program is being lead by Lockheed Martin Maritime Systems & Sensors business unit Under this business unit resides renewable energy pursuits in ocean thermal energy conversion, concentrated solar, photo-voltaic solar, wave energy, and biofuels.

Lockheed Martin's formal OTEC efforts started in 1974 when Lockheed Missiles & Space Company, Inc., a subsidiary of Lockheed Aircraft Corporation, supported by Bechtel Corp and T.Y. Lin International, began a "9-month study of the practicality of generating electrical power at competitive bus bar prices by using the solar energy that is stored as a thermal gradient in the world's oceans." That study was performed for the National Science Foundation's Research Applied to National Needs program partly in response to the increase in fossil-fuel costs (notably oil) in late 1973. Government direction of the program moved to the Energy Research and Development Administration when that organization was activated in January 1975. Lockheed followed with a self-funded 4-month demonstration called Mini-OTEC in 1979, with support from the US Navy, Makai Ocean Engineering, Dillingham Construction, and other firms. The Mini-OTEC plant was highly successful and remains the only floating, net-power producing OTEC plant ever built. Mini-OTEC was operated by the Lockheed Martin team for four months off the Big Island of Hawaii to gather technical data on the operation of the system as well as to prove the feasibility of clean electricity production using ocean temperature differences in an environmentally benign way.

The current LM OTEC program restarted in 2006 when Makai Ocean Engineering, Inc. invited

Lockheed Martin to support their SBIR project. We have since formally teamed with Makai to pursue OTEC commercialization for commercial and Department of Defense applications. Technology has advanced in many of the areas needed to make OTEC economically and technically feasible. Lockheed Martin is currently engaged in Internal Research and Development activities aimed at design of a modern era OTEC power plant. The Lockheed Martin OTEC team represents skills in large systems integration & engineering: identifying key technology areas for risk and cost reduction, incorporating relationships with small business partners, and leveraging skills and capabilities across the LM Corporation.

In addition to leveraging cross-corporate resources, we are working with other companies and universities who have expertise in the technologies and processes crucial for the successful commercialization of this renewable energy source. Lockheed Martin has both won grants and made internal investments to develop an OTEC Pilot Plant focusing on critical technology areas, such as the cold water pipe and heat exchangers to reduce technical risk and overall costs. In addition to our investment in the technology side of OTEC, we are also working to understand the potential and environmental limitations for OTEC to support a range of global energy and water requirements. We are leading studies to model the large volume water discharges that are inherent to OTEC. We are also actively communicating with the Federal, State, and Local regulatory agencies that oversee consultation and permitting and we have initiated an outreach program to local community leaders and a wide variety of environmental groups.

2.3.2 Equipment and Facilities

Lockheed Martin facilities are located in Manassas, Virginia. Computational facilities include a WAN based computer network with each person assigned a general purpose laptop or desktop computer. In addition, high-end workstations are available for computationally intensive processing. Several of these are currently assigned to ocean thermal energy related efforts.

Lockheed Martin engineers have shared license access to MatLab, MathCad and a full set of related tool boxes for these packages required to develop the OTEEV model. In addition, the OTEEV project has access to modern finite element packages and fluid flow code.

Of interest but not of direct applicability to the OTEEV effort, Lockheed Martin also had a mini-OTEC laboratory in Manassas that was used to test heat exchanger concepts. Other Lockheed Martin sites are currently testing coldwater pipe concepts; heat exchanger concepts, corrosion and biofouling; OTEC related manufacturing methods and heat exchanger performance. Knowledge and experience gained from those activities are available to leverage for the OTEEV project.

As part of FAU's effort, internal databases are available to collect and store the large amounts of information acquired. Three major areas of physical hardware infrastructure are required to accomplish the effort: database storage, database backup, and communications bandwidth to transfer data on and off-site. FAU provides multi-terabyte RAID 5 (minimum) hard disk storage capability for live use of the database(s). The data stored on the system not only has the natural "live" backup available from the redundant array setup, but is also backed-up as part of the internal storage and information backup schema which involves regularly scheduled back-ups both on and off-site. Transferring information off-site is made possible by an advanced network and telecommunications infrastructure available to FAU through its participation with Internet2, Florida LambdaRail, and the National LambdaRail. Bandwidths on the order of Gigabit Ethernet make possible large transfers of information between users.

The SOEST at UH maintains numerous facilities for oceanographic, atmospheric and planetary sciences. In addition to ocean observing resources (ships, fixed platform and a cabled observatory), the researchers on this proposal have access to large-scale computing resources including supercomputers and massively parallel machines. Researchers also have personal workstations fully capable of supporting the work outlined in this proposal.

Over the past ten years, a broad partnership of institutions under a NOPP sponsorship has developed and demonstrated an eddy-resolving, real-time global- and basin-scale ocean prediction systems based on the HYCOM. There are presently two models in use and that are run in real time by the US Navy at NAVOCEANO, Stennis Space Center, MS, and by NOAA at NCEP, Washington,

DC. This work will utilize the global US Navy nowcast/forecast system with the 1/12° global HYCOM (6.5-km grid spacing on average, 3.5-km grid spacing at the North Pole, and 32 hybrid layers in the vertical). This model, which has been running daily since 2006, consists of a five-day hindcast and a five-day forecast. The system assimilates 1. sea surface height (Envisat, GFO, and Jason-1), 2. sea surface temperature (all available satellite and in situ sources), 3. all available in situ temperature and salinity profiles (e.g., Argo, CTDs, moorings), and 4. Special Sensor Microwave/Imager (SSMI) sea ice concentration. While no new runs will be performed for this work, the existing 4 years of data will be utilized to fill measurement gaps.

NREL's Data Analysis and Visualization group is responsible for hosting some of NREL's most visited websites (430,000 page views for the GIS homepage http://www.nrel.gov/gis in 2008); highlighting U.S. renewable resources with interactive maps, static maps, geographic analysis, and data download capabilities. The data and websites are housed on multiple web and file servers, making use of commercial and open source software to provide fast and easy access to multiple databases. NREL's GIS databases include annual average and time series resource datasets for wind, solar, biomass, and geothermal; base political, demographic, environmental and infrastructure data (elevation, land use, census, cities, roads, counties, etc.); and publicly available imagery services. Additional licensed or proprietary databases can be incorporated into interactive maps and access controlled through user password access. These databases may include electricity infrastructure (transmission lines, substations, etc.) or confidential measurement locations.

NREL also maintains the Renewable Resource Data Center (RReDC), (http://www.nrel.gov/rredc/), a separate web site which is a central repository for all kinds of non-GIS renewable resource databases. RReDC provides detailed resource information through tools, reports, maps, and data collections for biomass, solar, wind and geothermal resources. Links are provided to data residing on NREL's GIS web sites as well as to outside sources of renewable resource data.

Future NREL plans include development of a data center with capabilities to further expand network bandwidth and enable transfers of larger volumes of data.

2.3.3 Team Member Participation

Lockheed Martin – Lockheed Martin is the prime contractor for OTEEV. As such, LM is responsible for overall program management and contract administration. In addition, Lockheed Martin is developing the OTEEV model.

Laura Martel – Program Manager

Robert Howard – ECM Development PI

Florida Atlantic University – FAU is technical authority for OTEEV. As such, FAU is providing technical leadership and coordination among the technical team. In addition, FAU is providing the OTEEV input dataset in conjunction with the University of Hawaii.

Dr. Frederick Driscoll – OTEEV Technical Director, FAU PI

Dr. Howard P. Hanson – OTEEV Deputy Technical Director

Dr. James VanZwieten – OTEEV input dataset generation

Ms. Anna Leland – OTEEV input dataset generation

University of Hawaii – UH is providing the ocean circulation expertise for the OTEEV project. UH provides analysis of ocean data and processes and contributions to the OTEEV input dataset

Dr. Richard Rocheleau (HNEI) – UH OTEEV Project Leadership

Dr. James Potemra (HIGP) – OTEEV ocean circulation PI

National Renewable Energy Laboratory – NREL is the GIS authority for OTEEV. As such NREL provides the integration of the OTEEV output dataset into a publically accessible GIS database that constitutes the OTEEV tool. In addition, NREL is providing independent validation and verification (V&V) of the OTEEV data, methodology and results.

Thomas Stoffel – NREL OTEEV Project Leadership